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ORIGIN OF PHYSIOLOGIC FORMS OF *PUCCINIA GRAMINIS* THROUGH HYBRIDIZATION AND MUTATION*

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Introduction

It has long been suspected that new physiologic forms of *Puccinia graminis* Pers. might arise through hybridization and mutation. In 1918, Stakman, Piemeisel and Levine (*16*) suggested this possibility, and in 1919, Stakman, Levine and Leach (*15*) made the following statement in an attempt to explain the existence of so many physiologic forms of *P. graminis tritici* Erikss. and Henn.:

> "Many of the virulent forms seem to occur in the Northern States, where everyone will now concede that the barberry is of tremendous importance in the persistence of stem rust from year to year. Eradicate the common barberry and there is reason to believe that these forms may gradually die out entirely, or at least be reduced to a condition bordering on impotence. The fact also that in the South and on the Pacific Coast, where barberry does not rust commonly, the forms of rust seem to be more uniform than in other regions, certainly lends some colour to the view that the barberry may have some effect on their development. A hypothesis that forms may have originated by hybridization on the barberry may be worth investigating. Of course mutation and adaptation must be considered also in any attempt to explain how so many forms originated."

Hayes and Stakman (*8*) make the following statement regarding the possible origin of physiologic forms of *P. graminis tritici*:

> "Stakman and others (1918) have suggested three possible causes of the origin of biologic forms. These are gradual adaptation, mutation and hybridization. No evidence of mutation or gradual adaptation has been obtained as a result of numerous and extensive experiments both with the uredinial and aecial stages of many biologic forms. The practical importance of knowing whether new forms are constantly arising would seem to warrant further studies. It appears that if a biologic form was homozygous for its inheritance factors that no change should be expected during its life history in any state unless a cross

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occurred between two biologic forms. This could conceivably take place upon the barberry. If, however, a biologic form was heterozygous for its inheritance factors it would seem that segregation might occur at the time of teleutospore formation in the spring. Two or more racial strains might then occur from a single form. The possibility that the forms which give X reactions are heterozygous and therefore somewhat less stable in their manner of reaction seems worth considering. A promising mode of determining a possible origin of the numerous biologic forms would appear to be to study the stability of a series of forms immediately after they had been grown on barberry. Definite hybridization studies might be made, although some difficulties of crossing biologic rust forms are apparent."

Stakman, in a paper read at the International Congress of Plant Sciences in 1926 (*12*), made the following statement regarding the possible origin of physiologic forms of hybridization:

"Do physiologic forms of pathogenic fungi hybridize? There is no reason why they should not; it would be strange if they did not. Saito and Naganishi (67) and Blakeslee (9) long ago showed that there were different sexual strains of the Mucorales and that they could hybridize. The more recent work of Kniep (49), Buller (18), Hanna (38), and others is very suggestive in this respect. Is there any reason why different physiologic forms of rust fungi, for instance, may not hybridize in the aecial stage? It seems almost a foregone conclusion that they sometimes do, but I know of no case in which it has been conclusively demonstrated. Levine and I have obtained circumstantial evidence that different forms of *P. graminis* hybridized on the barberry and produced new forms, but we could not prove it conclusively with our material."

It seemed perfectly obvious to most practical students of *P. graminis* that hybridization and mutation would most satisfactorily account for the existence of the large number of physiologic forms within several of the rust varieties, especially *P. graminis tritici.* Particularly strong evidence lies in the fact that physiologic forms clearly seem to differ from each other genotypically and not merely phenotypically, as had been supposed by many of the earlier investigators.

Craigie's (*3, 4, 5*) important demonstration that *P. graminis* is heterothallic and his brilliant discovery of the function of the pycnium not only virtually confirmed the suppositions regarding hybridization but also furnished a simple and precise technique for making crosses between varieties and forms of the rust.

Waterhouse (*17*) intermixed the pycnial material of two collections of wheat rust in Australia and obtained from the resulting aecial material two forms of *P. graminis tritici* which never had been found in that country. Waterhouse expressed the opinion that the new forms "had their origin in the phase of the life history on barberry". He had good circumstantial evidence that the two new forms were developed as a result of the mixing of pycnial material of forms 34 and 43. He observed also that the results afforded the strongest reason for eradicating barberries, and he suggests

that the large number of physiologic forms of *P. graminis* in North America, where barberries are wide-spread, may be the result of hybridization on barberries, while the paucity of forms in Australia may be due to the scarcity of barberries in that country. In a second paper Waterhouse (*18*) gives further evidence that new forms may originate on barberry.

Dietz (*6*), studying the possible effect of Rhammus spp. on the infection capabilities of the aeciospores of *Puccinia coronata* Cda., obtained the following results: *P. coronata festucae* Erikss., a narrowly specialized variety of crown rust, which does not ordinarily produce infection on *Andropogon, Bromus, Hordeum, Lolium, Phalaris,* and *Stipa,* produced abundant infection on certain species, when they were inoculated with aeciospores from *Rhammus lanceolata* Pursh, infected with teliospores from *Festuca elatior* L. Dietz did not offer any explanation for his results, but they would seem to indicate that the crown rust had gone through a profound genetic change during its sojourn on the aecial host.

While it has been suspected for some time that mutations may occur, there seemed to be good evidence that they occurred rarely if at all. The first conclusive demonstration of mutation in *P. graminis* was made by Newton and Johnson (*10*) who, in 1927, described colour mutations. Waterhouse (*18*), in Australia, observed similar mutations in the colour of uredinia. This discovery made it seem probable that mutations in pathogenicity might also occur, but so far as the writers know, it has not heretofore been conclusively demonstrated.

Results of Investigation

The present paper gives in some detail the results previously reported in a preliminary way by the writers (*14*) and includes also those obtained subsequent to that report.

Hybridization

At various times since 1919 the writers made attempts to obtain evidence of hybridization between varieties or forms of *Puccinia graminis.* However, the results of the experiments either miscarried, or were inconclusive. The first difficulty encountered was the production of teliospores of known forms under conditions that insured purity. The second difficulty was the capricious germination of teliospores, and the third was the fact that no precise technique was known for actually making the crosses. Craigie's researches, previously referred to, solved the problem of technique for making crosses, but the other two difficulties to a large extent remained. The writers decided, therefore, to attempt crosses between known varieties instead of forms within the varieties.

It was decided, for two reasons, to make crosses first between *P. graminis tritici* and *P. graminis agrostidis* Erikss. These two rust varieties do not attack the same group of hosts, the former develops well on wheat, barley, and many grasses, while the latter is restricted to *Agrostis spp.* and several wild grasses which are not congenial hosts for the *tritici* variety. Stakman, Piemeisel and Levine (*16*), in 1918, reported unexplained results of inoculating barberry with teliospores from *Agrostis stolonifera* L. Wheat, oats and rye became infected with the resulting aeciospores, whereas, normally none should have been infected. While these unexpected results may pos-

sibly have been due to faulty technique, it seemed possible that hybridization might have accounted for them. It was suggested by Levine (*9*) that "It is not impossible, therefore, that we are dealing here with a genuine case of segregation [in the telial stage] and recombination of genetic characters of a heterozygous rust in the aecial stage during the process of nuclear division and fusion."

Results of Intermixing Pycnial Nectar of *P. graminis tritici*, and of *P. graminis agrostidis*.

Barberry plants, protected by insect cages lined with two layers of fine-mesh muslin, were inoculated, some with teliospores on wheat from Montana, and some with teliospores on *Agrostis alba* L., from Minnesota. As soon as pycnial nectar became abundant, "reciprocal crosses" were made. In addition, some of the pycnia were "selfed". The results are given in table 1. When nectar from *tritici* pycnia was transferred to *agrostidis* pycnia, no aecia resulted. When, however, the transfer was made in the opposite direction, aecia were formed in every case. From the selfed pycnia of the *tritici* variety, only *P. graminis tritici* 36, described by Stakman and Levine (*13*), was obtained in each of four trials. The selfing of *agrostidis* resulted only in *agrostidis*. From the four *tritici* × *agrostidis* crosses, however, 12 distinct forms were isolated. From the cross designated in table 1 as number 5 eight distinct forms were obtained. Three of these had never been found previously, one had been known only in Portugal, and another had been isolated rarely and only from aecial material, in the field. Furthermore, these eight forms apparently came from a single aecial cup. Transfers from this single cup were made very carefully. The results obtained are outlined in figure 1.

Table 1—*Physiologic forms obtained from reciprocal crosses* (*a*) *on Berberis vulgaris of Puccinia graminis tritici with Puccinia graminis secalis and with Puccinia graminis agrostidis, respectively.*

Source and date of pycnial-nectar combinations			Uredinial Progeny
No.	Crosses	Date	
1	*P. gr. tritici* 36 x *P. gr. agrostidis*	10/7/28	*tritici* 36, 61, 21, 17
2	*P. gr. agrostidis* x *P. gr. tritici* 36	do.	No aecia formed as result of cross
3	*P. gr. tritici* 36 x *P. gr. agrostidis*	3/4/29	*tritici* 32
4	*P. gr. agrostidis* x *P. gr. tritici* 36	do.	No aecia formed as result of cross
5	*P. gr. tritici* 36 x *P. gr. agrostidis* (*b*)	do.	*tritici* 36 (*c*), 69, 67, 52, 10, 38, 58 (*d*), 61, 72
6	*P. gr. tritici* 36 x *P. gr. secalis* 11	do.	*tritici* 36, 15
7	*P. gr. secalis* 11 x *P. gr. tritici* 36	3/9/29	*secalis* 9, *tritici* 57
8	*P. gr. secalis* 11 x *P. gr. tritici* 36	3/30/29	*secalis* 11
9	*P. gr. tritici* 36 x *P. gr. secalis* 11	4/15/29	*tritici* 32
10	*P. gr. secalis* 11 x *P. gr. tritici* 34	do.	*secalis* 11
11	*P. gr. secalis* 11 x *P. gr. tritici* 36	9/17/29	*secalis* 11
12	*P. gr. secalis* 11 x *P. gr. tritici* 36	9/19/29	*tritici* 36
13	*P. gr. secalis* 11 x *P. gr. tritici* 36	do.	*tritici* 21, 70, 71
14	*P. gr. tritici* 36 x *P. gr. secalis* 11	11/14/29	*tritici* 67 (Auburn) (*e*)

(*a*) The word "cross" is used to designate the mixing of pycnial nectar;
(*b*) From one of the aecial cups resulting from this cross eight distinct physiologic forms of *P. graminis tritici* were isolated, viz. forms 10, 38, 52, 58, 61, 67, 69 and 72;
(*c*) Two varicoloured strains of *P. graminis tritici* form 36—a brown and an auburn one—were isolated from two different aecial cups of the *tritici* x *agrostidis* cross,
(*d*) Three varicoloured strains of form 58—argus brown, mars yellow, and dull auburn—were isolated from an inoculation with aeciospores from the same cup;
(*e*) Pathogenicity the same as of form 67 in experiment 5, but uredinia dull auburn instead of argus brown. All the colour determinations were made with the aid of Robert Ridgway's "Color Standards and Color Nomenclature". Washington, D. C. 1912.

Discussion of results presented in figure 1.—In only one case (table 1, exp. 5) was more than one physiologic form isolated from a single aecial cup. This is outlined diagrammatically in figure 1, series b. It is necessary to emphasize again that there is no way of knowing that accidental contamination has been avoided. From this *tritici* × *agrostidis* cross the following eight distinct forms of *P. graminis tritici* were isolated, namely, forms 10, 38, 52, 58, 61, 67, 69 and 72. Of these, forms 67, 69 and 72 are new to science; form 58, was hitherto unknown in North America, although it has been found in Lisbon, Portugal; form 61 is of very rare occurrence and had been previously isolated from field collections of aecial origin only; form 38 is of frequent occurrence and of wide distribution; whereas both 10 and 52 are rather infrequent and fairly limited in their distribution. None of the forms isolated from this cross infected species of *Agrostis.*

In pathogenicity form 52 resembles the parent form 36 very closely, differing from it only in that Vernal emmer is very susceptible to 52 but highly resistant to 36. Form 61, like 52, differs from form 36 in one respect only, but in this case there appears to be a loss of virulence for one of the differential hosts, viz. Kanred. Form 67 is very similar to form 52, but it produces a very distinct type X on Acme, whereas Acme is completely susceptible to 52. Form 69 has greater virulence than the parental form 36 on Kubanka and Vernal, but causes no infection on Kanred and Kota and, on the average, can produce only a weak type 2 infection on Marquis. Form 10 differs from form 36 not only in that it is unable to infect Marquis and Kota normally, but that, unlike form 36, it is very virulent on Arnautka, Mindum, Spelmar and Kubanka. Form 38 is considerably more virulent than form 10 on Kota but is somewhat less virulent than form 10 on all of the durum differentials, on which it produces the heterogeneous type X infection. Form 58 produces type X infection on Little Club and Marquis, otherwise it is essentially the same as form 69, The chief difference between form 72 and form 58 is that 72 produces a noticeably heavier infection on Khapli, which may be designated either as X ± or 3 $+^{cn}$. The parasitic behaviour of all of these forms is given in detail in table 2.

That the forms described in Figure 1 were actually the result of crosses between *P. graminis tritici* and *P. graminis agrostidis* cannot, of course, be stated with absolute certainty. This, however, is true: Whenever the parental forms were selfed, that is, when the pycnial nectar of *tritici* or *agrostidis* was mixed with nectar of its own kind, only the respective rust varieties appeared from the subsequent aecial inoculations. Furthermore, in the case of selfing *P. graminis tritici,* the only physiologic form that resulted from the aecia produced was *P. graminis tritici* 36. The test was repeated four different times under different conditions, but the results in each case were the same. It would, therefore, seem that the *tritici* parent used in this experiment was not only apparently free from a physical admixture of other rust forms but was also relatively homozygous. Nevertheless, the possibility always remains that other forms may have been present in the telial material, or that the rust was heterozygous, or both. In any event, eight different physiologic forms were isolated from what appeared to be a single aecial

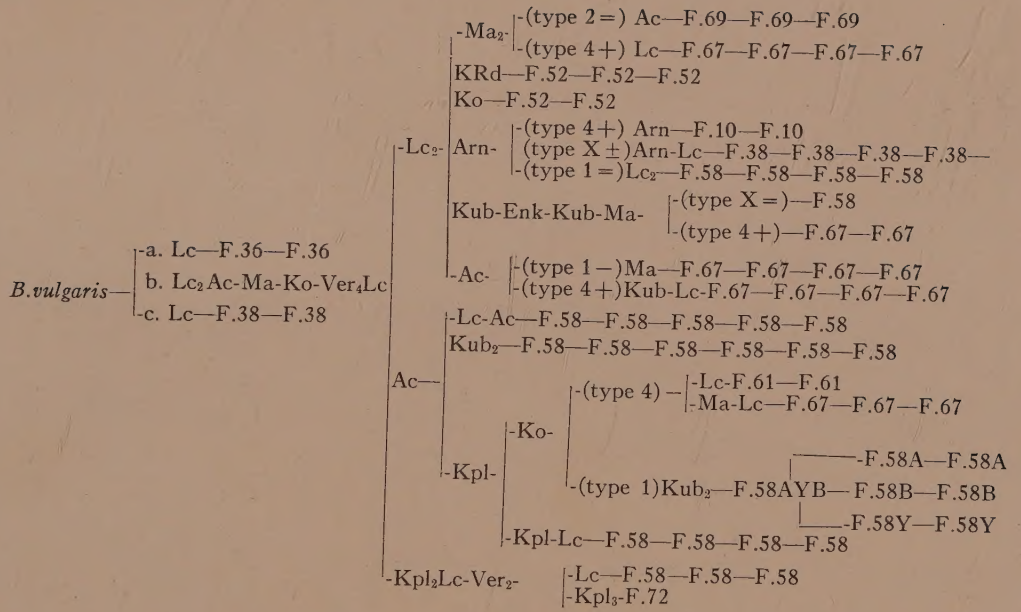

Figure 1—Condensed diagram illustrating procedure of isolating physiologic forms which resulted from crossing individual pycnia of *Puccinia graminis agrostidis* with single pycnia of *P. graminis tritici* form 36. Individual aecial cups were used to inoculate plants of cereals and grasses. Only *P. graminis tritici* resulted from the cross. From Little Club plant (a) form 36 was isolated, from plant (c) form 38. The culture on plant (b) yielded eight distinct physiologic forms, as shown in the diagram above, namely forms 69, 67, 52, 10, 38, 58, 61, and 72. In one case three varicoloured strains of form 58 were isolated, viz.; Argus Brown, Mars Yellow, and Dull Auburn.

Explanation of abbreviations and symbols—A = Dull Auburn, Ac = Acme, Arn = Arnautka, B = Argus Brown, Enk = Einkorn, F. = Physiologic form, Ko = Kota, Kpl = Khapli, KRd = Kanred, Kub = Kubanka, Lc = Little Club, Ma = Marquis, Ver = Vernal, Y = Mars Yellow. Indices beneath lines indicate number of successive uredinial generations on given host.

TABLE 2—*Pathogenicity of physiologic forms of Puccinia graminis tritici used as parents in pycnial crosses on Berberis vulgaris and of those isolated from subsequent aecial inoculations on the differential varieties of Triticum spp.*

Physiologic forms	Mean reaction of differential varieties*											
	Little Club	Marquis	Kanred	Kota	Arnautka	Mindum	Spelmar	Kubanka	Acme	Einkorn	Vernal	Khapli
10	4++	2−	3++	2±	4+	4++	4+	3++	4±	3+	1=	1=
15	4+	4±	4−	4	4++	4+	4++	4+	4±	4−	4	1−
17	4	4−	0	3++	4+	4	4	4−	4=	3++	0;	0;
21	4±	4+	0.	3++	4±	4	4+	4	3++	1=	1−	0;
32	4+	4	4−	3+	X	X+	X±	X−	X+	4−	1=	1=
34	4+	4−	4−	4=	4	4	4−	4	3++	1=	1=	0;
36	4	4+	4	4=	0;	0;	0;	X++	4=	3++	0;	1=
38	4±	2−	4−	3++	X+	X±	X+	X++	X+	4−	1=	1+
52	4	4	4−	4	1=	1−	1=	X±	4	4−	4+	1−
57	4	4−	0.	3+	1	1	1	4	3+	3	3	1
58	X+	X+	0	0;	1+	1=	1±	4+	3+	3++	4+	1+
61	4+	4	0	3+	0;	0;	0;	X	4+	4	0;	0;
67	4±	4+	4	4	1±	2=	2=	X=	X+	3−	4±	1−
69	4	2±	0	0;	0:	1±	1−	4+	4±	4=	4+	2=
70	4+	X+	0;	1=	0;	0;	0;	0;	0;	0;	X±	0;
71	4+	X−	0	0;	0;	1=	0;	1=	0;	0;	0;	0;
72	X±	2−	0.	0;	2±	1++	2−	4+	4=	4−	4+	X±

*Explanation of symbols: O—absolute immunity, 1—extreme resistance, 2—moderate resistance, 3—moderate susceptibility, 4—complete susceptibility, X—indeterminate reaction, (;) hypersensitive flecks, (.) necrotic lesions, (:) hypersensitive islands; plus and minus signs indicate a slightly greater or smaller amount of rust than the nearest figure representing the infection types; c=chlorosis, n=necrosis.

cup, all of the forms isolated were evidently of the *tritici* variety, three of these were hitherto entirely unknown, one had not previously been found in North America and one had been found only on barberry. None of the forms were particularly virulent, but some of them were more virulent than the parental *tritici* form. While some unusual infection was produced by one of the new forms—in that the practically universal resistance of Khapli was at least in part overcome, in the case of another form, the uredinia were of three different colours, mars yellow, argus brown and dull auburn, respectively.

Results Obtained from *secalis* × *tritici* Crosses

In a cross between *P. graminis secalis* Erikss. and Henn. form 11, described by Cotter and Levine (*2*), and P. *graminis tritici* form 36, (table 1, exp. 7) the *secalis* form 9 and the *tritici* form 57 were isolated from different cups. In both cases the progeny was different from the parents involved. The only difference in the pathogenicity between the two *secalis* forms is in the reaction of Prolific rye. As may be seen from table 3, this differential variety is fairly susceptible to form 9 and intermediate in reaction to form 11. *P. graminis tritici* 57 differs considerably from *P. graminis tritici* 36. The former is unable to attack Kanred at all—a loss of virulence compared with form 36, and attacks Vernal very heavily—an acquisition of virulence; furthermore, Kubanka is very susceptible to form 57 but indeterminate to form 36.

Table 3—*Pathogenicity of physiologic forms of Puccinia graminis secalis that were involved in pycnial crosses with Puccinia graminis tritici on Berberis vulgaris or were isolated from subsequent aecial inoculations on differential varieties of rye.*

Range of infection of physiologic forms	Relative susceptibility of differential varieties *				
	Petkus Minn. Acc. No. 86	Rosen Minn. Acc. No. 82	Swedish Minn. No. 2	Prolific Minn. Acc. No. 89	Dakold Minn. Acc. No. 93
Form 9					
Minimum	75.60	77.78	45.19	76.89	11.18
Maximum	87.19	91.08	51.08	83.00	19.00
Mean	83.35	87.45	47.64	78.92	17.27
Form 11					
Minimum	76.72	81.55	32.08	37.50	5.77
Maximum	93.62	99.11	61.89	68.29	23.32
Mean	89.04	89.33	45.45	54.15	18.18

* Three host reaction classes—resistant, susceptible and intermediate—are recognized in the identification of physiologic forms of *P. graminis secalis*. A variety is considered resistant when less than 25 per cent of the infected plants show normal development of rust; when 75 per cent or more of the infected plants are heavily rusted the variety in question is considered to be susceptible; the host reaction is considered intermediate when more than 25 but less than 75 per cent of the infected plants have normal rust pustules, or when the infection on all or most of the plants is heretogeneous.

Form 11 of the *secalis* variety and form 36 of the *tritici* variety were used also in another cross. In this case (table 1, exp. 13), the resultant forms, isolated from different aecial cups, were all of the *tritici* variety and consisted of forms 21, 70 and 71. All of these three forms are very different from the parental form 36, but while form 21 is in a sense somewhat more

virulent than form 36, the other two forms are unusually weak in pathogenicity on the differential hosts of *Triticum spp.* The outstanding differences between forms 21 and 36 are, on the other hand, the loss of virulence in form 21 on Kanred and Einkorn, and, on the other hand, an increase of virulence on Arnautka, Mindum and Spelmar. In addition, Kubanka, on which form 36 produces only the X type infection, is very susceptible to form 21.

Forms 70 and 71, obtained from the last named *secalis* × *tritici* combination are of unusual interest. Their behaviour points quite definitely to the fact that they probably resulted from a genetic cross. Neither form can infect normally the varieties of rye used as differential hosts and they can infect only a few of the wheat differentials. Both can attack Little Club wheat, form 70 produces a type X infection on Marquis and Vernal, and form 71 produces type X on Marquis, but cannot produce even that type of infection on Vernal. All of the other wheat differentials are completely resistant to or absolutely immune from both forms. It certainly would seem that these forms, neither of which has ever been reported previously, must have resulted from plasmogamy or some other interaction between the *secalis* and the *tritici* varieties, following the intermixing of pycnial nectar of the two.

When *P. graminis tritici* 36 was crossed with *P. graminis secalis* 11 (table 1, exp. 14), a form of *P. graminis tritici* resulted in the subsequent uredinial generation, which was identified as form 67. On the basis of the infection it produced on the 12 wheat differentials it was identical with the form 67 produced by the *tritici* × *agrostidis* cross. The pustules of the two forms, however, differ radically in colour, those of the *tritici* × *secalis* being dull auburn, and of the *tritici* × *agrostidis* cross argus brown.

Mutation

It appears from the studies of many rust workers that the inherent parasitic capabilities of physiologic forms and varieties of rust do not change readily. It has therefore been assumed that, at least under experimental conditions, pathogenic mutation in the rust fungi is infrequent if it occurs at all. However, in a uredinial culture of *P. graminis tritici* form 1, constant pathogenically for more than 13 years, there suddenly appeared a new form (subsequently identified as *P. graminis tritici* form 60) different parasitically from anything the writers had hitherto known. Extensive inoculations, as shown in table 4, proved its constancy.

Form 60 is distinguished from form 1 in two essentials, a loss in the capacity to produce normal infection on either Kubanka or Einkorn. Two other mutants that arose from form 1—forms 21 and 17— are much more virulent than the original culture. Form 17 can infect all the differential varieties of wheat that form 1 can and, in addition, can produce heavy infection on Arnautka, Mindum and Spelmar, which form 1 cannot infect to any extent. Form 21 is somewhat less virulent than form 17 in that Einkorn is highly resistant to it. Just recently still another form has split off from the

TABLE 4.—*Summary of inoculation results of Puccinia graminis tritici form 1, cultured continuously for more than 13 years, and of Puccinia graminis tritici form 60, forma nova, which arose from form 1 as a result of mutation.*

Infection data	Reaction of differential hosts											
	Little Club	Marquis	Kanred	Kota	Arnautka	Mindum	Spelmar	Kubanka	Acme	Einkorn	Vernal	Khapli
Form 1												
Number of trials	144	38	51	25	26	28	16	27	14	23	16	12
Plants inoculated	1971	397	553	334	277	254	150	245	141	235	166	132
Plants infected	1772	373	50	241	177	212	137	212	132	221	147	100
Lowest infection	3+	3	0	3−	0;	0.	0;	3=	3−	3−	0.	0;
Highest infection	4++	4++	0;	4+	1	1+	1±	4+	4+	4+	1+	1++
Average infection	4	4−	0	3++	1=	1	1−	3+	3++	3+	0;	1=
Form 60												
Number of trials	7	5	6	6	5	4	5	6	6	6	6	5
Plants inoculated	426	213	321	284	275	177	161	385	308	283	278	162
Plants infected	394	205	53	267	208	173	141	300	277	267	216	151
Lowest infection	4	4=	0	3++	0;	0;	0;	0;	3+	0;	0;	0;
Highest infection	4++	4++	0;	4+	1−	1−	1=	1+	4+	1+	1+	1+
Average infection	4+	4	0.	4−	0;	0;	0;	1=	4=	1−	1	1−

original culture, and although not yet fully identified, it, like form 60 (the first mutant), seems to be entirely different in behaviour from anything hitherto described. The new mutant has been designated as form 68.

Conclusions

It now seems perfectly clear that physiologic forms of *Puccinia graminis* come into being through hybridization and mutation. The evidence adduced by Waterhouse (*17, 18*), by Newton, Johnson and Brown (*11*), and by the writers shows rather definitely that hybridization may result in the production of many new forms. Waterhouse and Newton et al, also have observed mutations in colour of uredinia. The writers of this paper believe they have presented proof also of mutation in pathogenicity. This would indicate that physiologic forms of these pathogenic rust fungi originate in the same way as other organisms.

Physiologic forms of *P. graminis* are constant as long as they are propagated in the uredinial stage. They are dikaryotic clones whose pathogenic properties depend on the genetic factors in the dikaryon the conjugate nuclei. These conjugate nuclei fuse in the teliospores and the fusion nucleus evidently undergoes reduction division before sporidia are formed. The sporidia then, are haplonts, and different sporidia may have different factors for sex and for other characters, including pathogenicity. The sporidia infect the barberry and pycnia (spermagonia) containing haploid pycniospores (spermatia) result. When plasmogamy occurs between spermatia of opposite sex, aecia are formed, and a new dikaryophase begins. The pathogenic capabilities of the dikaryophytes obviously must depend, therefore, on the factors for pathogenicity in the dikaryons—that is, the two associated haploid nuclei.

If barberries are infected with a single form of *P. graminis* and the spermatia are "selfed", the aeciospores would have the same pathogenic capabilities as the preceding uredinial stage, provided the form was homozygous for pathogenicity. If, on the other hand, the form was heterozygous, the aeciospores might differ pathogenically from the uredinial stage. There is no assurance, therefore, that physiologic forms will retain their identity in passing through the barberry. That they sometimes do, however, is shown clearly by the results of numerous inoculations made from material collected in the field, and by the fact that *P. graminis tritici* form 36, when selfed in experiments made by the writers, came through the aecial stage unchanged. When "crosses" are made between different forms, the characters of the resulting dikaryophytes would depend, of course, on the factors in the two nuclei, one of each form, in the dikaryon. That nuclear association in the dikaryophytes influences the general characters, including pathogenicity, is evident both in the rust and in the smut fungi.

The barberry therefore serves a double function as far as the development of physiologic forms of *P.graminis* is concerned. Whether hyphal fusion takes place at the pycnium as thought by Allen (*1*), or at the base of the aecium as stated by Hanna (*7*), the barberry is the only place where the results of segregation can become effective. That most of the physiologic forms now in existence probably resulted from hybridization

rather than mutation is suggested strongly by the fact that a large number of forms can be obtained by making crosses on the barberry, and also by the fact that mutation in parasitism seems to be relatively rare, at least as far as our present limited knowledge of the frequency of such mutation gives evidence.

The results show conclusively that the eradication of the barberry is imperative as a practical rust control measure. It is basic to progress. In addition to the fact that in temperate regions a large amount of early inoculum comes from infected barberries in the spring, it may now be safely concluded that many of the physiologic forms probably depend upon the barberry for their survival. Furthermore, the ultimate results of hybridization that has occurred in the past would not have been realized had the barberries been eradicated. The eradication of the barberries therefore very probably will result in a reduction of the number of physiologic forms already in existence and will prevent the formation of large numbers in the future. Hybrids resulting from unusual chance combinations would tend to disappear because of dearth of inoculum and scarcity of barberry. Consequently, barberry eradication is extremely important in several ways in the control of rust. By combining eradication with a widespread use of rust-resistant varieties, the amount of inoculum will be reduced both in the aecial and uredinial stages, so that this doubly reduced inoculum together with the scarcity of barberries will diminish the opportunities for the formation of new and possibly dangerous forms of the rust. The fact that the writers obtained a form of *P. graminis tritici,* as a result of hybridization, that was more virulent than any form hitherto collected in North America, suggests strongly that all possible combinations of pathogenicity have not yet been made.

It seems clear, therefore, that the results obtained by the writers and other investigators in this field show clearly that physiologic forms of *P. graminis* are not of a single genetic origin but may arise through hybridization on the barberry and through mutation in at least the dikaryophase. From a practical standpoint the eradication of barberries from important grain growing regions now takes on a new and important significance, not only as a means of reducing the amount of inoculum, but also as a factor in the reduction in number and prevention of formation of new and dangerous forms, and as an aid and protection in the stability and development of rust-resistant varieties of cereals.

Summary

1. In an attempt to prove the long-held conviction that physiologic forms and varieties of the cereal rusts arise through hybridization, reciprocal crosses were made between *P. graminis tritici* and *P. graminis secalis* and between *P. graminis tritici* and *P. graminis agrostidis.*

2. From a single aecial cup produced as a result of intermixing pycnial nectar of *tritici* × *agrostidis,* eight distinct physiologic forms of *P. graminis tritici* were isolated, some of which had not been identified previously. Some of the forms differed in virulence from the *tritici* parent, one was able to infect even Khapli emmer moderately; while the uredosori of another form differed markedly in colour.

3. Two forms obtained as a result of the *secalis* × *tritici* crosses were much less virulent on the differential varieties of wheat than the *tritici* parent, but one of them inherited from its *secalis* parent the ability to infect slightly the rye differentials.

4. In a uredinial culture of *P. graminis tritici* form 1, collected in 1915 and constant pathogenically for over 13 years, four distinct forms of *P. graminis tritici* appeared successively two of them heretofore unknown. The mutants were consistent pathogenically during a succession of uredinial generations on the wheat differentials.

5. These results, and those of other investigators, indicate that varieties and physiologic forms of *P. graminis* may be considered as dikaryotic clones that remain constant in the uredinial stage, except for mutation. They may, however, lose their identity in passing through the barberry because of segregation in the promycelia of the teliospores, or because of the initiation of a new dikaryophase in the pycnia or aecia.

6. Because of the fact, therefore, that the barberry may be the breeding ground for new and possibly dangerous forms of stem rust, the results from a practical standpoint constitute an additional argument for barberry eradication.

Acknowledgements

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A PRELIMINARY STUDY ON THE HYBRIDIZATION OF PHYSIOLOGIC FORMS OF *PUCCINIA GRAMINIS TRITICI* * †

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The fact that *P. graminis tritici* Erikss. and Henn. is not a simple species but consists of a large number of strains, or forms, which differ markedly in their ability to attack different varieties of wheat, has been a very great obstacle to the plant breeders in their attempt to develop varieties of wheat that are highly resistant to stem rust. No doubt plant breeding for rust resistance offers the most plausible and satisfactory method of controlling stem rust, but the work of Craigie (*3, 4*) has shown quite clearly that there is the possibility that two physiologic forms of stem rust might hybridize on the barberry and thus produce a new physiologic form which might possibly be more virulent than any of the forms hitherto discovered. Such an eventuality might seriously impede plant breeding work or even render it more or less futile.

Theoretically, new forms may arise in three ways, (1) by adaptation of an existing form, (2) by mutation of an existing form and (3) by hybridization of two existing forms on the barberry. No positive evidence of adaptation has yet been found. Mutations in colour in *P. graminis tritici* have already been described by Newton and Johnson (*9*) and Waterhouse (*14, 15*). Recently a mutation in parasitism in *P. graminis tritici* was reported by Stakman, Levine, and Cotter (*13*). Craigie (*4*) in 1927, showed that *P. graminis tritici* is heterothallic, and furnished a technique by which the possibility of hybridization between species, and physiologic forms, of rust fungi might be experimentally investigated.

A study of the physiologic forms of stem rust present in Canada was made by the writers (*10*) during 1926, 1927 and 1928. Eight physiologic forms different from any previously described forms were isolated. One of these forms originated in aeciospores produced on a barberry plant which was artificially inoculated in the greenhouse. The aeciospores arose as a result of mixing pycnial nectar, and were given by J. H. Craigie to the writers (*10*) for identification of the physiologic forms. Most of the new forms originated in Eastern Canada from aeciospores, or from urediniospores collected in areas where barberries are commonly grown. Practically no barberries are present in Western Canada. In nature, therefore, physiologic forms appear to be hybridizing on the barberry with the production of new physiologic forms.

Recent publications by other investigators have likewise supported this view. Waterhouse (*14*) reported on the origin of two new Australian forms

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†In this issue of *Scientific Agriculture* appears also a paper by Stakman, Levine and Cotter dealing with hybridization and mutation in *Puccinia graminis*. The simultaneous publication of these two papers has been pre-arranged by the authors.

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of *Puccinia graminis tritici*, which resulted from crosses between two known physiologic forms. Stakman, Levine and Cotter (*13*) have recently succeeded in crossing *Puccinia graminis agrostis* and *Puccinia graminis tritici* form 36.

The present authors (*11*) have made a preliminary announcement on the crossing of different physiologic forms of *Puccinia graminis tritici* and also on experiments on the selfing of individual forms. The present paper gives a detailed account of this work.

The writers undertook an experimental investigation of the problem. Their two main objects were, (1) to self physiologic forms, that is, to intermix the nectar on the pustules derived from the same physiologic form to determine if the forms were homozygous or heterozygous and (2) to cross physiologic forms, that is, to intermix the nectar of two monosporidial pustules derived from two physiologic forms, and to study the progeny.

Material and Methods

The first attempt to carry out this study was made in 1926 when, in the greenhouse, a number of monosporous cultures of two physiologic forms were allowed to go into the telial stage. These telia were over-wintered out of doors but failed to germinate the following spring. Again in 1927, this experiment was repeated with monosporous cultures of several physiologic forms. The teliospores of two of the forms germinated in the spring of 1928, namely, the orange mutant of form 9a* and the greyish-brown mutant of form 36. Each of these forms, after having passed through the barberry, gave rise to the original mutant form. With some of the over-wintered telial material two more barberry plants were inoculated, one by the orange mutant of form 9 and one by the greyish-brown mutant of form 36. Monosporidial pustules of each form were obtained. An attempt was then made to cross the orange with the greyish-brown rust by applying the nectar of pustules derived from the orange rust to pustules derived from the greyish-brown one. As a result of this mixing of nectar, there arose a rust of normal colour which was identified as form 17a*. The results of this work will be published in the near future.

In the experiments discussed in this paper, the method of inoculating barberry plants was as follows. A lantern chimney was placed over the barberry to be inoculated, and on top of the lantern chimney was placed a petri-dish cover lined with damp blotting paper, to which were fixed rusted pieces of straw bearing germinating telia of one physiologic form (Figure 1). When this was done the plant, still enclosed by the chimney and petri-dish cover, was placed in a damp incubation chamber. The petri-dish cover was revolved from time to time so as to secure an even distribution of sporidia on the leaves of the plant. At intervals of a few hours, the plant was atomized with a fine spray of water in order to maintain a film of moisture on the leaves.

*To these forms, Marquis and Kota were somewhat more resistant than to forms 9 and 17 respectively, as indicated by the sharp chlorosis and the smaller type of pustule; but these differences were not considered to be sufficiently great to justify the creation of two new and distinct forms.

Figure 1. A barberry plant enclosed by glass chimney and petri-dish cover during inoculation.

If a physiologic form was to be selfed, the petri-dish cover was not removed until the end of forty-eight hours, so that the plant might become heavily infected.

If two physiologic forms were to be crossed, two barberry plants were inoculated, each one with a different form. In this case, the petri-dish covers were removed at the end of from four to six hours, but the plants were left in the incubation chambers for forty-eight hours.

As all the telial material used in these experiments had developed in the greenhouse, germination was not so abundant as in ordinary field collections and, consequently, the time necessary for inoculation was relatively long.

When the inoculated plants were removed from the incubation chamber, they were placed separately on greenhouse benches. As soon as infection became apparent, each plant was covered with a screen wire cage to prevent insects from visiting the pustules.

If the form was to be selfed the pycnial nectar of the various pustules was intermixed by means of a sterilized needle about ten days after the barberry had been inoculated with a physiologic form.

If, however, two forms were to be crossed, two weeks were allowed to elapse after the pustules first appeared before any cross was made, as, by that time aecia would have developed in all compound pustules, the components of which were of opposite sexes. The work of Craigie (*3, 4*) had shown that (1) when two spordia of opposite sex, (+) and (—), fall close together on a barberry leaf so that the pustules arising from the two infections soon coalesce, aecia are produced; (2) when, however, two spordia of

the same sex, that is, two (+) sporidia or two (−) sporidia, fall close together so that the two pustules arising from the two infections soon coalesce, no aecia are produced. Pustules of this second type could not always be distinguished readily from monosporidial pustules. A pustule of this type is referred to later.

The method followed in crossing two physiologic forms is illustrated diagrammatically in Figure 2.

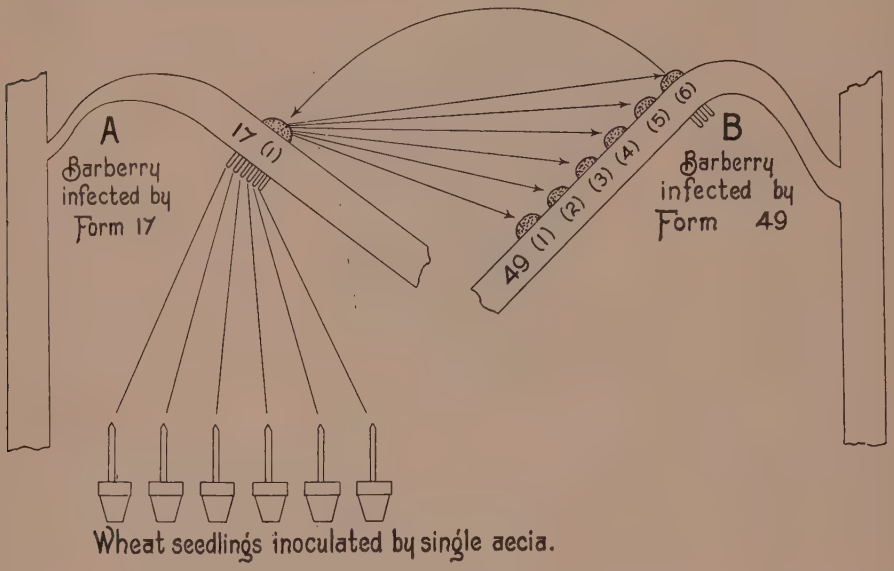

Figure 2. Diagram illustrating the method followed in crossing two physiologic forms.

The barberry on the left of the figure (A) was inoculated by form 17, the one on the right (B) by form 49. When abundant nectar had developed on the pustules of both barberries, some of the pycnial nectar from a monosporidial pustule of (A) was successively transferred to the six monosporidial pustules of (B) by means of a platinum loop which was sterilized after each transfer by passing it through a flame. To complete the cross, nectar from pustule (6) of (B) was then transferred back to the monosporidial pustule of (A) from which the nectar had been first taken. A small tag showing the date on which the cross was made and other information was attached to the leaves bearing pustules used in the operation.

As the amount of nectar produced by a single pustule was often limited, a modification of the above method was sometimes adopted. This consisted in removing the nectar of the monosporidial pustule from which transfers were to be made, and mixing it with a drop of distilled water on a watch glass. The nectar thus diluted, was then successively transferred to other monosporidial pustules in the manner previously described. It was interesting to note that in these crosses the diluted nectar appeared to be as efficacious in inducing the formation of aecia as was the undiluted nectar.

When a cross had been made between two physiologic forms and aecia had developed, ten to fifteen cups were selected from each pustule. Each

aecial cup was carefully picked off by means of sterile forceps, crushed on a sterile glass slide, and the contents of each cup used to inoculate a single wheat plant of Little Club. After rust had appeared on this wheat plant, other plants of the same variety were inoculated to increase the inoculum sufficiently for transfer to the differential hosts used in the identification of physiologic forms. Only barberries bearing unopened aecia were used in this work. This precaution was taken as earlier experiments had shown that aeciospores shot out from open cups might adhere to cups on the same leaf, or even on other leaves.

When a form had been selfed, the same procedure was used except that a number of cups were selected at random from as many aecium-producing pustules as possible in order to obtain an adequate index of the physiologic forms present.

Results

The result of selfing eight physiologic forms is shown in Figure 3. Segregation occurred in all the forms except one. For example, form 17 gave rise to eight different forms, form 49 to nine forms, form 21 to six forms and form 53 to eighteen forms. Form 9 was the only one which did not break up.

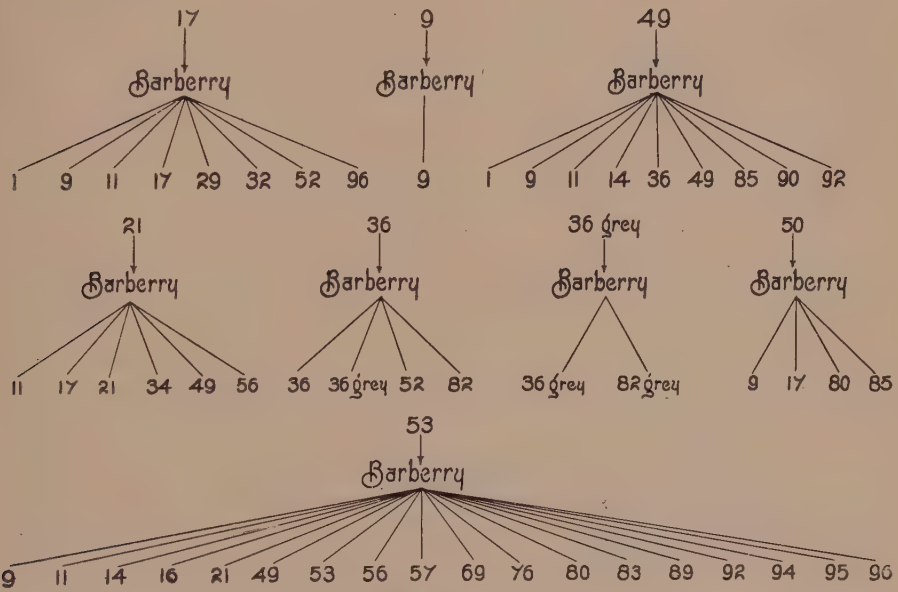

Figure 3. Diagram showing forms that arose from the selfing of eight physiologic forms.

Of the forms that arose from this selfing, twelve were new forms* and eighteen were old forms (see 5, 7, 8, 10). The reactions of the new forms on the twelve standard differential hosts are given in table 4.

In table 1 is given a more detailed analysis of the data graphically presented in Figure 3, with a similar analysis for form 52. The first column includes a list of the forms that were selfed, the second column the forms

*The writers are indebted to Dr. E. C. Stakman and Dr. M. N. Levine for assigning numbers to the new physiologic forms.

Table I. The genotypic constitution of 9 physiologic forms, determined by the reactions of their progeny on differential hosts.

Original form	Forms isolated with no. of cultures of each in parenthesis	No. forms isolated	Conclusions
9	9 (40)	1	homozygous
17	1 (7); 9 (2); 11 (9); 17 (15); 29 (5); 32 (3); 52 (1); 96 (1).	8	heterozygous
21	11 (7); 17 (1); 21 (5); 34 (3); 49 (4); 56 (3).	6	heterozygous
36	36 (23); 36 grey (4); 52 (8); 82 (1).	4	heterozygous
36 grey	36 grey (5); 82 grey (9).	2	heterozygous
49	1 (1); 9 (1); 11 (1); 14 (1); 36 (1); 49 (2); 85 (1); 90 (2); 92 (1)	9	heterozygous
50	9 (1); 17 (1); 80 (5); 85 (1).	4	heterozygous
52	30 (1); 36 (1); 36 grey (1); 40 (1); 49 (1); 52 (29); 52 grey (5); 81 (1).	8	heterozygous
53	9 (1); 11 (1); 14 (7); 16 (1); 21 (5); 49 (1); 53 (3); 56 (2); 57 (4); 69 (2); 76 (1); 80 (5); 83 (1); 89 (1); 92 (6); 94 (1); 95 (1); 96 (1)	18	heterozygous

that arose from each form after it had been selfed on the barberry and the number (in brackets) of cultures of each form recovered. For example, when form 21 was selfed, twenty-three single aecial cups were picked off at random from the barberry plant inoculated with this form. Seven of these cups gave rise to form 11, one to form 17, five to form 21, three to form 34, four to form 49 and three to form 56. The third column gives the number of forms isolated, and the fourth column the conclusion concerning the genetic constitution of the original form.

As crosses between homozygous forms had been planned, it was disappointing to find only one form homozygous. However, the crosses listed on page 727 were made. The results of these crosses are given in Figure 4. The circles represent the forms used in the crosses, and the squares the number of single cups in each pustule from which cultures were obtained. Although from ten to fifteen cups were selected from each pustule, not all of them produced infection. Therefore, the number of cultures secured do not necessarily represent the number of cups that were picked off.

The crosses are numbered from I to IV, each cross being made on two separate barberry plants, the one inoculated with one physiologic form, the other with another physiologic form. In crosses II, III and IV, the same forms were crossed, but different pairs of barberry plants were used for each cross.

Cross Number I was made between forms 15 and 9. The pycnial nectar of a monosporidial pustule of form 15 was intermixed with the pycnial nectar of a monosporidial pustule of form 9. Both pustules produced aecia from which form 9 only was obtained.

Cross Number II was made between forms 49 and 17. Form 30 only was obtained from these two pustules.

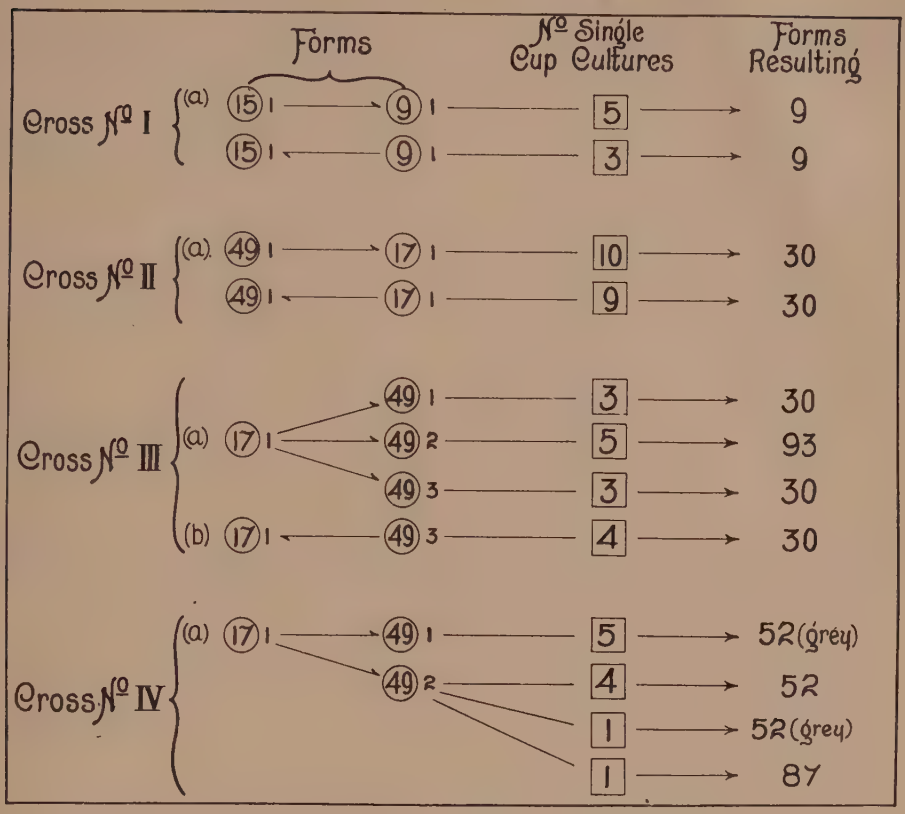
Forms
No Single Cup Cultures
Forms Resulting
Cross No I
(a) 15 1 → 9 1 → 5 → 9
15 1 ← 9 1 → 3 → 9
Cross No II
(a) 49 1 → 17 1 → 10 → 30
49 1 ← 17 1 → 9 → 30
Cross No III
(a) 17 1 → 49 1 → 3 → 30
→ 49 2 → 5 → 93
→ 49 3 → 3 → 30
(b) 17 1 ← 49 3 → 4 → 30
Cross No IV
(a) 17 1 → 49 1 → 5 → 52(grey)
→ 49 2 → 4 → 52
→ 1 → 52(grey)
→ 1 → 87

Figure 4. Results of crosses between physiologic forms.

Cross Number III was made between forms 17 and 49. In this cross the pyncial nectar of a monosporidial pustule of form 17 was transferred to three monosporidial pustules of form 49, pustules (1), (2) and (3). The reciprocal cross was made by intermixing the pycnial nectar of pustule (3) of form 49 with the pycnial nectar of pustule (1) of form 17. Since forms 17 and 49 are both heterozygous, different forms might be expected to arise from the three monosporidial pustules (1), (2) and (3) of form 49. The expectation was fulfilled. Form 30 was recovered from pustules (1) and (3), but a new form, 93, was recovered from pustule (2). In the reciprocal of 17 × 49, namely, pustule (1) of form 17 and pustule (3) of form 49, form 30 was obtained.

Cross Number IV was also made between forms 17 and 49. The pycnial nectar of a monosporidial pustule of form 17 was transferred to pustules (1) and (2) of form 49. The reciprocal was not made. From pustule (1) of form 49 was recovered form 52 (greyish-brown); from pustule (2) of form 49 three forms were recovered, 52, 52 (greyish-brown), and a new form, 87. This seeming anomaly can be explained by assuming that pustule (2) of form 49 was of compound origin, derived from two or more sporidia of the same sex. In all the other crosses, one form only occurred in each pustule.

This is, of course, what would be expected. Nevertheless, it was found that when the nectar of a number of monosporidial pustules, derived from several physiologic forms, was mixed indiscriminantly, two or more forms were frequently isolated from an individual pustule. On the other hand, it had been noticed that although several physiologic forms arose in one pustule, yet as a rule not more than one physiologic form was obtained from any one aecium.

In order to secure more experimental evidence on this relationship—one form from one cup—the following experiment was undertaken. A barberry plant was inoculated simultaneously with eight physiologic forms, and, as a result of this inoculation, a heavy infection of the leaves was secured. Both simple (monosporidial) and compound (multisporidial) pustules appeared. The pycnial nectar of all the pustules was thoroughly inter-mixed. As will be seen from table 2, seventy-three isolations were made from these aecia. From these cultures seventeen forms were identified, of which ten were previously known, and seven were new.

Table 2. Results of crosses between eight physiologic forms of P. graminis tritici

Forms used simultaneously to infect barberries		Forms isolated from mixture		No. of times each form isolated
9		9		5
17		17		5
34		34		3
49		49		6
		33		4
		36		7
		50		1
		53		20
		52		1
		56		2
		79		1
		81		8
		82		1
		85		4
		87		1
		90		1
		91		3
Total no. of forms	8	Total no. of forms isolated	17	Total no. of cultures 73

Sixty-four of the aecial cups arising from this infection were chosen at random, cultured separately, and resolved into their component physiologic forms. Although the sixty-four aecial cups produced many forms yet with one exception, each individual cup produced but a single form.

As the experiment just described indicated quite clearly that a single aecial cup gives rise to a single physiologic form, all the earlier experimental data were examined to ascertain what proportion of the single cups had given rise to one form per cup. These data do not include the forty cups that were derived from form 9, the homozygous form, as all these cups gave rise to form 9, nor do they include the cups arising from crosses between forms, as only one form had been isolated from the cups of each pustule,

except in the case already noted. It will be seen from table 3, that of the two hundred and seventy-six remaining cups cultured, two hundred and sixty-two of these, or 95 per cent of the cups, produced one form each, while fourteen out of the two hundred and seventy-six, or 5 per cent, produced

Table 3. The proportion of single aecial cups giving rise to one, two or three physiological forms respectively.

Total number of single aecial cup cultures	Number of cups giving rise to one form only	Number of cups giving rise to 2 forms	Number of cups giving rise to 3 forms	Percent of cups giving rise to more than one form
276	262	13	1	5.1

two or more forms each. Cotter (*2*) has found that more than one physiologic form may be isolated from a single aecial cup, but if the data given above can be considered as an index of the number of forms present in a cup, the evidence indicates that the normal condition is one form to one cup.

TABLE 4. *Mean infection produced by seventeen new physiologic forms of Puccinia graminis tritici on differential varieties of Triticum spp.*

Physiologic forms	Lc.	Ma.	Krd.	Ko.	Arn.	Mnd.	SpM.	Kub.	Ac.	Enk.	Ver.	Kpl.
76	4	4−	0	3+	X	X	X	X	3+	3+	X−	1
79	4	4−	0	1−	1−	1−	1−	4−	3+	0;	3+	1
80	4	3c	0	3−	0;	0;	0;	X−	3+	1−	3+	1
81	4	X	0	1+	4	4	4	4	4−	1−	1−	1−
82	4	3+	3+	3+	0;	0;	0;	X	3+	3+	X	1
83	4	1+	3−	1−	3+	3+	3+	3+	3+	3+	3+	1
85	4	4−	0	3±	4−	4	4	4	4	3+	X	1
87	4	4	4	3±	4	X	X	X	3+	3+	4	1
89	4	2	3+	0;	4	X	X	X	3±	3+	3+	1
90	4	4	0	3±	4	X	X	X	3+	1	1	1
91	4	X	0	X	4	4	4	4−	3+	3+	X	1
92	4	X	0	X	1	1	1	4	4	1	1	1
93	4	3+	0	3=	0;	0;	0;	X	3±	3+	3+	1
94	4	X	0	X	4−	4−	4−	4−	3+	1	1	1
95	4	2	3±	0;	4	4	4	4	3+	1	1	1
96	4	X	4	X	4	4	4	4	3+	3+	1	1

Discussion

The results presented in this paper and those obtained by Allen (*1*), Craigie (*3, 4*), Hanna (*6*) and others leave little doubt that the pycniospores perform a very definite function in initiating the diploid condition of the mycelium in the aecial spore-bed with the subsequent formation of aecia. In most of the crosses here recorded the hybrid forms were intermediate in pathogenicity between the two parental forms, as judged by the reactions of the twelve differential hosts. This fact suggests that the nuclei of the pycniospores and the nuclei of the sporidia contribute about equally to the inheritance of the hybrid. It appears, therefore, that when a cross is made, the nuclei of the pycniospores come into conjugate relationship with the nuclei of the haploid mycelium, thus initiating the formation of the diploid aeciospores which contain some of the hereditary factors of the two parental forms.

It has been shown that when a cross was made, namely, when the pycnial nectar of a (+) monosporidial pustule derived from one physiologic form was applied to a (—) monosporidial pustule derived from another form, only one physiologic form was recovered from the aecia which developed in the latter pustule. From this fact it may be assumed that all the aecia of that pustule contained aeciospores which were identical in their genotypic constitution.

Furthermore, it has been shown that when the pycnial nectar of pustules derived from eight physiologic forms was intermixed, the aecia of any one of the pustules gave rise to several physiologic forms, but no single aecium—with one exception—to more than one form. It may therefore be assumed that in any one of these pustules the aeciospores of one aecium might have differed in their genotypic constitution from the aeciospores of another aecium, but, in any given aecium, the aeciospores were genotypically alike. The fact that in 63 out of 64 aecia, only one physiologic form was represented in any individual aecium, shows quite clearly that the condition of one form to one aecium is not a mere coincidence.

How this condition arises awaits elucidation. The evidence, however, indicates that in the same aecium the conjugate pair of nuclei of one aeciospore is genetically identical with the conjugate pair of another aeciospore. If it is assumed that one member of each conjugate pair of nuclei is of pycniosporic origin and the other of hyphal origin, derived from the haploid hyphae in which the aecium arises, it would appear that all the conjugate nuclei of an aecium are descended from two nuclei which had become associated in conjugate relationship.

When more than one physiologic form is recovered from an aecium, as is the case in 5 per cent of the aecia (table 3), it is evident that the conjugate nuclei of all the aeciospores are not descended from a single conjugate pair. Two or more genetically different pairs must be involved. There is also the possibility that, in some cases, the occurrence of two or more forms in a culture derived from a single aecium may be due to contamination that occurs during the process of culturing. In the identification of physiologic forms this possibility cannot be entirely eliminated even with the greatest precautions.

Summary

1. Crosses have been made between a number of physiologic forms. In all cases but one the hybrid forms were different from the parental forms. Some of the hybrid forms are new, others are identical with previously-known forms.
2. By selfing experiments it has been discovered that the majority of forms are heterozygous. At least one form, form 9, is homozygous.
3. In 95 per cent of the aecia studied, not more than one physiologic form was isolated from each individual aecium.

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PASTURE INVESTIGATIONS ON THE SHORT GRASS PLAINS OF SASKATCHEWAN AND ALBERTA.*

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Research on problems pertaining to pasture improvement has received a great stimulus during the past decade. British workers have given much consideration to the fundamental factors underlying good pasture management. Among their more recent researches are those conducted by Stapledon and his co-workers at the Welsh Plant Breeding Station, Aberstwyth, Wales, by Woodman and his colleagues at Cambridge University, England, by members of the staff of the Rowett Research Institute, Aberdeen, Scotland, and by the Research Division of the Imperial Chemical Industries Limited, Jealott's Hill, Warfield, England.

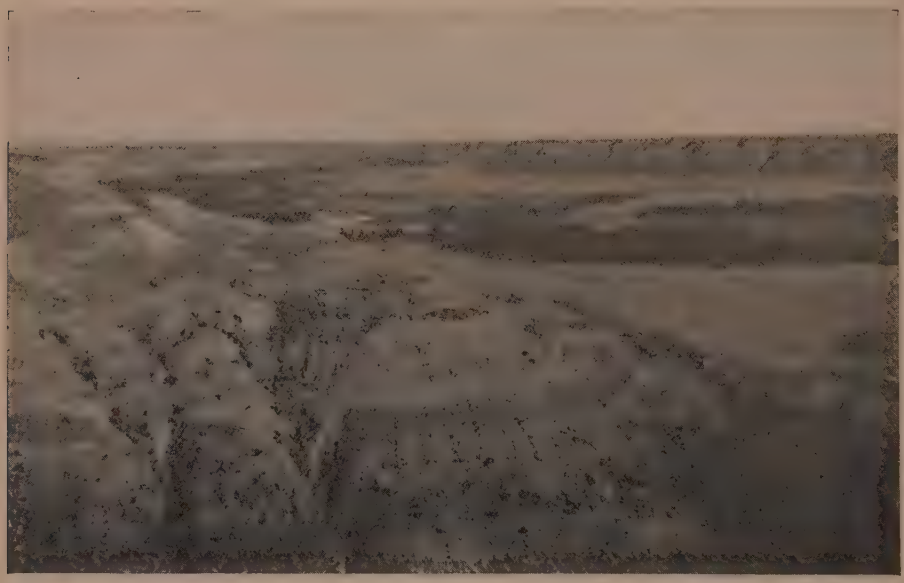

Figure 1. Milk River Valley, just north of the Montana border, in southeastern Alberta. The banks are steep and badly eroded.

During the world war, Germany was forced to supply feed for stock from her own lands, and therefore gave much attention to her pastures. Professor Warmbold introduced the Hohenheim System, "The New System of Grassland Management". This system involves (1) the division of the pasture area into smaller plats, (2) the division of the grazing herd according to production, (3) an intensive system of fertilization with special attention to high nitrogen applications and (4) frequent rotation of the various groups of stock in such a manner as to allow the high-producing cows to graze the

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plats first, thus obtaining an abundance of fresh grass that is high in protein and digestible food.

Workers of other counties, including Aston (*2*) of New Zealand, and Bews (*3*) and Leppan (*11*) of South Africa have contributed much to our knowledge on the subject.

In the United States much research work is being done on pasture management, both on the dry range lands of the West and in the more humid sections of the East. Old empirical methods are being discarded and a close study is being made of the effects of various treatments and grazing practices on the botanical and chemical composition of the vegetation. A great number of workers including agronomists, botanists, chemists and members of other divisions are spending the whole or a part of their time on pasture studies, and many Range Experimental stations and sub-stations have been established in the Western States. Administrative bodies and research workers of the United States are cognizant of the economic importance of their pasture lands. Chapline (*4*) states that nearly 70 per cent of the feed for all the livestock in the eleven far Western States is obtained from grazing the native forage on timber and other range lands.

In Canada, very little research work has been done on pasture management and very few systematic ecological studies have been made of the vegetation on pasture lands. Agriculture has been, and still is, the basic industry of the Dominion and animal husbandry is one of the chief branches of that industry. In Eastern Canada there are millions of acres of pasture lands, the Province of Quebec alone having over three and a half million acres of land that is used for pasture purposes. In Saskatchewan and Alberta about ten million acres are used for grazing purposes, slightly over half of which is leased from the Government. Over ten thousand grazing leases are held in these two provinces. In British Columbia several large areas of mountain and plateau lands are used for range purposes. It is estimated that the losses incurred due to the improper management of our pasture lands amounts to many millions of dollars annually.

In Western Canada, the lack of research work on pasture management may be attributed largely to the following conditions, (1) Previous to the advent of the dry land farmer in the early years of the present century, there was an abundance of forage for all classes of livestock on the range lands, (2) projects pertaining to pasture improvement are relatively costly and (3) in the past, administrative bodies, agronomists and farmers alike have concerned themselves chiefly with the production of cash crops. Pasture lands were looked upon by many as waste lands, and few sensed their real value and economic importance.

Twenty years ago it was quite generally thought that wheat could be grown profitably in the semi-arid portions of southern Saskatchewan and Alberta, and many homesteads were granted in areas that previously had been used for range purposes only. These dry land farmers tried to make a living by growing wheat. In many parts they succeeded and prosperous farming communities now exist as a result of their efforts. In other parts,

however, the nature of the physical controls together with the long distance from markets made wheat growing unprofitable and the settlers were forced either to abandon their farms and move out or to change over to mixed farming or ranching.

This westward invasion of the farmers together with an increase in the numbers of the stockmen, brought the free range era to an end as far as Southern Saskatchewan and Alberta were concerned. Ranchers were forced to buy or lease land for grazing purposes and to fence those lands and to restrict their stock to smaller areas. Divisional fences had to be erected and in many cases additional watering places had to be developed. These factors greatly increased the ranchers' overhead expenses.

Following the year 1916 the range areas experienced a long succession of dry years and after the war prices of livestock dropped to very low levels. Many of the range areas became badly overgrazed and their carrying capacity seriously lowered. Such conditions made ranching unprofitable and some of the stockmen were forced out of the business.

The stockmen themselves were the first to realize that there was an urgent need for a sound, definite policy concerning the management of the range lands and the conservation of our grazing resources. In 1925 they approached the Dominion Government asking that certain alleviatory measures be taken. In answer to their requests a number of changes were made in the regulations. For instance, security of tenure was greatly enhanced by the extension of the term of lease to 21 years. The Experimental Farms Branch of the Department of Agriculture made a reconnaissance of the range lands of Saskatchewan and Alberta and subsequently established a Range Experimental Station on the short-grass plains in southeastern Alberta.

At this station and on adjacent range areas a large number of projects have been started, pertaining to (1) the management of livestock on the range, (2) a study of the botanical and chemical composition of the native vegetation, (3) a study of the effects of different grazing practices upon the vegetative cover, (4) the improvement and maintenance of range pastures and (5) the growing of forage crops for winter feed. As this station has been in operation for only two years, this paper must be considered as a preliminary report, and discussion will be limited to sections (2) and (3) as listed above.

The short-grass plains of southwestern Saskatchewan and southern Alberta comprise the largest range areas in Western Canada at the present time. The topography of these plains is gently rolling and in places they are cut by deep river valleys and by canyon-like coulees. The soil varies from a light sandy loam to a heavy clay loam, with certain areas strongly alkaline. Large areas are spotted with so-called "burn-out" depressions which vary in size from a square foot to several square rods and on which there is no humus and little or no vegetation. The average annual precipitation is approximately 13 inches. When not overgrazed, these plains produce a fairly good cover of palatable and nutritious grasses, except on such portions as may be strongly alkaline or badly eroded.

Figure 2. A "burn-out" spot on the short grass plains of southeastern Alberta.

A Study of the Native Vegetation

1. *Principal Species and their Palatability.*

The short-grass formation includes several outstanding plant associations. The most common and most valuable of these is the Bouteloua - Stipa - Koeleria group. While *Bouteloua gracilis* (Blue grama grass), *Stipa comata* (Spear grass) and *Koeleria gracilis* (June grass) are the dominant species, others commonly found include *Agropyron Smithii* (Blue Joint), *Agropyron dasytachyum* (Wheat grass), *Poa confusa, Poa laevigata, Poa crocata* (Meadow grasses) and *Carex filifolia* (Nigger wool)*. This association is found mostly on the open prairie and especially on loam or sandy loam soils. There are many modifications of this group, for instance, on deep sandy loam soils *Stipa comata* predominates, on shallow soils *Bouteloua gracilis* is most prevalent and on clay loams the Agropyrons and certain Poas are the dominant species. *Bouteloua consociations* are quite common on shallow soils, especially on southern slopes. The next most important group is the Agropyron-Poa association. This group is most prevalent on clay loam soils, and on partly eroded or silt covered areas. While the principal species are *Agropyron Smithii* and *Poa reflexa*, other species such as *A. dasystachyum, A. Richardsonii, A. tenerum, Koeleria gracilis, Stipa viridula* (short-awned needle grass) and several other Poas are commonly found interspersed among the dominants. *Agropyron Smithii* is usually the first grass species to invade badly eroded areas, burn-out spots and weed infested abandoned fields.

While the species already mentioned constitute the great bulk of the grass cover, other forms predominate on certain soil types, and under certain moisture conditions. Some of the more common of these are, (1) in sloughs and along streams; *Agrostis hyemalis* (Feather-grass), *Alopecurus Macounii*

*The word "grass" as used in this paper should be interpreted to include also Carex and Juncus species.

Figure 3. Knee-deep in Blue Grama (*Bouteloua gracilis*)

(Foxtail), *Poa triflora* (Meadow grass), *Beckmannia crucaeformis* (Slough grass), *Deschampsia atropurpurea* (Hair grass), *Hordeum jubatum* (Wild barley), *Carex atherodes* (Swamp grass), *Juncus balticus* (Wire grass), and *Torresia odorata* (Sweet grass), (2) on sand or light sandy loams; *Andropogon Hallii* (Beard grass) *Schizachyrium scoparium* (Red Beard grass) *Calamovilfa longifolia* (Sand grass) *Calamagrostis montanensis* (Blue stem) *Festua supina* (Sheep fescue), *Schedonardus paniculatus* (Finger grass), *Muhlenbergia cuspidata, Sporobolus asperifolius* (Drop-seed grass), *S. cryptandrus* (Tall- drop-seed grass) and *Eriocoma hymenoides* (Indian millet), (3) on strongly alkaline soils, *Distichlis stricta* (Alkali grass) *Puccinellia Nuttalliana* (Salt Meadow-grass) and *Spartina gracilis* (Marsh grass) and (4) on bench lands, *Avena Hookeri* (Hooker's oat) *Danthonia intermedia* (Wild Oat grass) *Festuca saximontana* (Fescue grass) *Festuca scabrella* (Tall Fescue grass).

Other grasses of lesser importance include *Bromus purgans* (Nodding brome grass) *Bromus tectorum, Elymus condensatus* (Wild Rye grass) *Elymus robustis* (Buffalo Rye) and *Elymus virginicus* (Lyme grass).

All of the grasses usually cure previous to the earliest fall frosts and therefore they make good forage for the late fall and winter months. Most of the species are quite palatable although a few such as *Calamovilfa longifolia, Schizachyrium scoparium, Spartina gracilis* and *Sporobolus cryptandrus* contain much silica and soon become very harsh. They are eaten most readily during their early growth stages and again during the winter months.

Many broad-leaved plants are indigenous to the short-grass plains. Some of them are valuable forage plants, many are of little or no value and a few

are actually poisonous to livestock. While it is not our intention to give a complete list of these plants, the names of a few of the more common species, together with their classification on the basis of their palatability for range cattle, are presented in table 1.

TABLE 1. *Broad-leaved plants, classified according to their palatability for range cattle.*

Plants readily eaten by cattle	Plants not readily eaten	Poisonous Plants
Atriplex Nuttallii (Salt Sage)	Achillea lanulosa (Yarrow)	Aragallus galisides (Purple Loco)
Atriplex argentea (Salt Bush)	Antennaria microphylla (Cat-paws)	Aragallus gracilis (Yellow Loco Weed)
Eurotia lanata (Silver Sage)	Artemisia frigida (Prairie Sage)	Delphinium bicolor (Dwarf Larkspur)
Endolepis Suckleyi (Pigweed)	Artemisia cana (Sage Brush)	Equisetum arvense (Horsetail)
Chenopodium Album (Lambs quarter)	Cheirinia inconspicus (Prairie Rocket)	Thermopsis rhombifolia (Prairie Bean)
Salsola pestifer (Russian Thistle)	Chrysopsis villosa (Golden Aster)	Toxicoscordion venenosum (Death camas)
Ctenophyllum pectinatum (White Pea)	Chrysothamnus frigidus (Rabbit Brush)	Cicuta maculata (Water Hemlock)
Diholcos bisulcatus (Purple Pea)	Comandra pallida (Bastard Toadflax)	
Homalobus tenellus (Trailing Pea)	Dasiphora fructicosa (Shrubby cinquefoil)	
Geoprumnon crassicarpum (Buffalo Bean)	Dondia depressa (Sea Blite)	
Vicia Americana (Purple Vetch)	Eriogonum flavum (Umbrella Plant)	
Vicia sparsifolia (Purple Vetch)	Grindelia squarrosa (Gum Plant)	
	Gutierrezia Sarothrae (Brown Weed)	
	Hymenoxys Macounii (Colorado Rubber Plant)	
	Lygodesmia juncea (Skeleton Weed)	
	Paronychia sessiliflora (Whitlow-wort)	
	Psoralea lanceolata (Sand Vetch)	
	Sarcobatus vermiculatus (Greasewood)	
	Selaginella densa (Little Club Moss)	
	Sphaeralcea coccinea (Globe Mallow)	

The palatability of a plant depends largely upon (1) its stage of development, (2) the season of the year and (3) the class of livestock concerned. Such plants as *Calamovilfa longifolia, Salsola pestifer* and *Chenopodium album* are eaten most readily while in the early growth stage, while *Artemisia frigida, Diholcos bisulcatus, Ctenophyllum pectinatum, Atriplex Nuttallii* and *Eurotia lanata* are relished most when more mature. Cattle eat *Artemisia frigida* more readily during the winter months than in the summer and more readily on hills and ridges than on lower ground. Sheep eat Sage Brush and most other weeds more readily than do cattle, and antelope thrive best when they have access to such plants as certain species of *Artemisia, Atriplex* and

Eurotia. Plants such as Sea Blite, Brown-weed, Prairie Bean and Gum plant are seldom if ever eaten by any class of livestock. Death camas poisons many sheep but very few horses or cattle, while Larkspur poisons cattle but does not seriously affect sheep.

2. *Chemical Composition of Native Pasture Plants*

In England and Scotland extensive investigations have been conducted concerning the nutritive value of pasture grass. Elliott, Orr and Wood (*8*) working at the Rowett Institute, Aberdeen, Scotland, have investigated the mineral content of pasture grass. Woodman and co-workers (*16, 17*) of Cambridge University, have reported the analyses of composite samples of pasture grass taken at ten different periods during each of the years 1925 and 1926. The average percentage compositions of these samples on a dry matter basis are given as follows:—

Year	Mean Dry Matter	Crude Protein	Ether Extract	Nitrogen free extract	Crude fibre	Crude ash
1925	24.05	23.88	5.13	43.42	14.95	12.62
1926	21.96	24.08	6.32	40.12	17.83	11.65

Cruickshank (*6*) and Fagan (*9, 10*) have reported the analyses of grass samples taken from different pastures. The latter, using samples from pastures of four different types found that there was a great variation in chemical composition. The crude protein content varied from 9.86 to 18.15 per cent. Underwood (*15*) in his investigations of Australian pastures gets very similar results. Composite samples from good and from poor pastures were analyzed separately and the results obtained are compared in the following table.

Comparison of average results as obtained from good and poor pastures.

Constituent	Average "Good"	Average "Poor"	"Poor" as a percentage of "Good"
Total Protein	14.24	7.14	50.2
Fibre	26.98	31.35	112.6
Calories per 100 grams	241	231	95.9
Total Ash	12.64	10.86	85.9
Silica-free ash	9.91	8.23	83.0
Lime CaO	1.89	1.93	102.1
Phosphoric Acid P_2O_5	0.625	0.427	68.3

In both of the cases cited, the protein content of grass from good pastures was found to be about twice as great as that of grass from the poorer pastures. As the botanical composition of the different pastures is not given, we cannot say to what extent this difference is due to a difference in the plant species present.

Ellenberger, Newlander, and Jones (*7*) have reported on the yield and composition of pasture grass in the State of Vermont. Enclosed plots in each of a large number of pastures were frequently lawn-mowed throughout the growing season. The clippings from each mowing were weighed, sampled, their dry matter contents determined, composited and analyzed. The results obtained are presented in table 2.

TABLE 2. *Compositions on a dry matter basis of composite samples representing the total yields of pasture grass from all pastures.*
(After Ellenberger, Newlander and Jones)

	Pasture Number	Dry Matter	Crude Ash	Insoluble Ash	Crude Protein	Crude Fibre	Nitrogen-free Extract	Ether Extract	Calcium	Phosphorus	Yield of Dry Matter
		%	%	%	%	%	%	%	%	%	lbs.
1925	1	26.98	11.23	4.19	22.80	14.86	47.92	3.19	0.841	0.293	1,200
	2	20.60	10.63	2.72	29.66	16.70	39.32	3.69	0.801	0.417	3,761
	3	20.39	11.57	4.56	23.93	17.51	43.26	3.73	0.741	0.397	2,799
	7	22.43	10.48	2.59	24.79	14.98	45.83	3.92	0.883	0.343	1,807
	8	25.93	15.66	8.33	24.99	17.62	38.03	3.70	0.594	0.366	2,114
	9	26.40	12.12	5.72	19.28	17.38	48.03	3.18	0.921	0.504	965
	10	23.10	13.85	5.15	24.11	18.36	40.26	3.42	0.974	0.277	2,571
1926	1	27.44	9.26	2.66	21.65	17.89	48.22	2.99	0.929	0.277	1,280
	2	19.82	10.09	2.32	26.09	18.01	42.13	3.68	0.787	0.383	4,031
	7	18.48	11.04	2.38	21.00	16.61	47.57	3.79	1.077	0.341	2,265
	8	23.31	9.05	2.57	22.69	20.04	44.23	3.99	0.644	0.369	2,049
	9	26.08	9.47	3.07	15.80	19.82	51.88	3.03	0.917	0.226	945
	10	21.48	11.55	3.63	19.51	19.74	45.76	3.45	0.889	0.535	2,518
	11	35.86	12.21	5.88	15.39	19.91	49.36	3.12	0.753	0.232	261
	12	39.37	17.88	11.23	11.79	21.01	47.04	2.29	0.742	0.165	507
	13	37.74	7.68	3.63	11.74	23.42	54.48	2.67	0.718	0.175	329
	14	36.74	14.81	8.90	9.80	23.87	49.21	2.31	0.659	0.142	326
Average			11.68	4.68	20.30	18.69	46.03	3.30	0.816	0.320	1,748

TABLE 3. *Composition of native pasture plants collected on the short grass plains of Saskatchewan and Alberta in 1927 and 1928.*

No.	Name	Date of Collection	Stage of Growth	MOISTURE FREE									
				Protein		Crude Fat		Nitrogen Free Extract		Crude Fibre		Ash	
				1927	1928	1927	1928	1927	1928	1927	1928	1927	1928
1	Stipa comata (Spear Grass)	March 25, 1928	1927 growth		2.83		1.46		49.72		40.13		5.86
2	Stipa comata (Spear Grass	June 3, 1928	Emerging from sheath		14.51		3.63		48.82		28.30		4.74
3	Stipa comata (Spear Grass)	June 27, 1927	Flowering	8.12		3.21		33.97		48.70		6.00	
4	Stipa comata (Spear Grass)	July 27, 1927	Late Milk	5.61		2.63		50.71		36.40		4.65	
5	Stipa comata (Spear Grass)	July 4, 1928	Dough		8.60		1.84		49.21		36.20		4.15
6	Stipa comata (Spear Grass)	Nov. 20, 1928	Cured		4.91		2.55		53.58		29.39		9.57
7	Stipa comata (Spear Grass)	Nov. 1, 1927	Cured	2.00		2.02		49.63		39.84		6.51	
8	Koeleria gracilis (June Grass)	March 25, 1928	1927 growth		2.29		.97		50.34		38.78		7.62
9	Koeleria gracilis (June Grass)	May 23, 1928	Emerging from sheath		15.53		2.14		46.56		28.61		7.16
10	Koeleria gracilis (June Grass)	June 27, 1927	Flowering	5.99		3.13		49.63		36.01		6.14	
11	Koeleria gracilis (June Grass)	July 1, 1928	Late flowering		9.72		1.84		45.46		33.96		9.02
12	Koeleria gracilis (June Grass)	July 4, 1928	Dough		8.20		1.41		36.34		33.86		10.19
13	Koeleria gracilis (June Grass)	July 18, 1927	Dough	4.89		3.67		47.95		35.60		7.89	
14	Koeleria gracilis (June Grass)	Nov. 1, 1927	Cured	1.37		1.04		46.24		35.61		15.72	
15	Agropyron Smithii (Blue Joint)	March 25, 1928	1927 growth		3.32		1.82		47.45		40.81		6.60
16	Agropyron Smithii (Blue Joint)	March 25. 1928	1927 growth		2.53		1.26		51.31		32.25		12.65
17	Agropyron Smithii (Blue Joint)	June 5, 1928	Pre-flowering		16.44		1.37		44.02		28.03		10.14
18	Agropyron Smithii (Blue Joint)	July 26, 1927	Flowering	7.62		2.58		45.86		36.84		7.10	
19	Agropyron Smithii (Blue Joint)	July 4, 1928	Late flowering		15.86		1.56		44.51		31.18		6.89
20	Agropyron Smithii (Blue Joint)	July 26, 1927	Dough	6.49		2.06		50.10		34.73		6.62	
21	Agropyron Smithii (Blue Joint)	Nov. 20, 1928	Cured		3.33		1.16		59.39		28.00		8.12
22	Agropyron Smithii (Blue Joint)	Nov. 1, 1927	Cured	3.54		2.94		45.53		33.12		14.87	
23	Bouteloua gracilis (Blue Grama Grass)	March 25, 1928	1927 growth		2.87		0.71		51.53		36.42		8.47
24	Bouteloua gracilis (Blue Grama Grass)	July 4, 1928	Early flowering		11.54		1.15		48.70		32.06		6.55
25	Bouteloua gracilis (Blue Grama Grass)	July 28, 1927	Flowering	7.59		1.84		48.04		32.63		8.89	
26	Bouteloua gracilis (Blue Grama Grass)	Aug. 12, 1927	Dough	5.65		2.12		54.74		31.53		5.96	
27	Bouteloua gracilis (Blue Grama Grass)	Aug. 27, 1928	Nearly ripe		8.09		1.94		50.04		34.26		5.67
28	Bouteloua gracilis (Blue Grama Grass)	Nov. 25, 1928	Cured		3.33		1.37		55.69		31.39		8.23
29	Bouteloua gracilis (Blue Grama Grass)	Nov. 1, 1927	Cured	2.14		1.69		50.83		33.70		11.55	
30	Agropyron spicatum (Blue-bunch wheat grass)	Sept. 25, 1927	Cured	6.02		3.32		42.55		36.24		11.87	
31	Poa laevigata (Meadow Grass)	March 25, 1928	1927 growth		2.47		1.20		49.14		41.27		5.92
32	Poa laevigata (Meadow Grass)	May 23, 1928	Emerging from sheath		13.84		2.02		47.07		31.21		5.66
33	Poa laevigata (Meadow Grass)	June 26, 1927	Flowering	5.84		2.96		47.54		36.69		6.97	
34	Poa laevigata (Meadow Grass)	July 15, 1927	Late dough	5.36		3.21		50.25		35.46		5.72	
35	Poa laevigata (Meadow Grass)	Nov. 1, 1927	Cured	.99		1.70		48.75		42.50		6.55	
36	Poa reflexa (Tall Meadow Grass)	July 26, 1927	Dough	2.13		2.35		49.99		40.68		4.85	
37	Poa triflora (Feather Grass)	Aug. 1, 1927	Dough	5.44		1.44		51.96		34.18		6.98	
38	Stipa viridula (Short-awned needle grass)	July 26, 1927	Dough	9.20		1.78		45.53		35.54		7.95	

TABLE 3. (*Continued*)

No.	Name	Date of Collection	Stage of Growth	MOISTURE FREE									
				Protein		Crude Fat		Nitrogen Free Extract		Crude Fibre		Ash	
				1927	1928	1927	1928	1927	1928	1927	1928	1927	1928
41	Beckmannia erucaeformis (Slough Grass)	July 27, 1927	Dough	3.40		3.57		51.57		32.47		8.99	
42	Beckmannia erucaeformis (Slough Grass)	June 25, 1928	Early flowering		11.36		1.56		46.05		34.22		6.81
43	Festuca scabrella (Tall Fescue Grass)	July 14, 1928	Early dough		5.97		1.58		47.25		37.18		8.02
44	Hordeum jubatum (Wild barley)	May 25, 1928	Pre-flowering		28.59		4.05		32.94		23.27		11.15
45	Avena Hookerii (Hooker's Oat)	July 14, 1928	Late flowering		6.27		1.56		45.49		36.65		10.03
46	Festuca ovina (Sheep's fescue)	June 24, 1928	Late flowering		6.20		2.18		51.62		33.27		6.73
47	Deschampsia atropurpurea (Swamp Grass)	June 28, 1928	Pre-flowering		7.53		1.63		38.29		42.23		10.32
48	Deschampsia atropurpurrea (Swamp Grass)	July 27, 1927	Dough	5.22		1.81		44.03		39.62		9.32	
49	Schizachyrium scoparium (Beard Grass)	Aug. 27, 1928	Ripe		4.93		2.31		50.01		37.97		4.78
50	Muhlenbergia cuspidata (Muhlenbergia)	March 25, 1928	1927 growth		4.10		2.73		52.93		33.45		6.79
51	Calamagrostis montanensis (Blue-stem)	March 25, 1928	1927 growth		2.26		1.54		44.73		39.52		11.95
52	Calamagrostis Langsdorfii (Pine Grass)	Oct. 15, 1928	Cured		3.56		2.33		20.21		54.43		19.47
53	Distichlis stricta (Alkali Grass)	March 25, 1928	1927 growth		3.43		1.88		61.91		24.43		8.35
54	Distichlis stricta (Alkali Grass)	June 13, 1928	Pre-flowering		15.43		1.95		47.60		26.69		8.33
55	Sporobolus cryptandrous (Drop seed grass)	Aug. 23, 1927	Cured	5.52		2.22		52.10		33.82		6.34	
56	Carex filifolia (Thread-leaved sedge)	Aug. 10, 1927	Cured	6.23		4.34		52.03		26.71		10.69	
57	Juncus balticus (Wire Grass)	Aug. 10, 1927	Flowering	10.93		1.89		47.72		30.25		9.21	
58	Carex atherodes (Slough Grass)	May 24, 1928	Pre-flowering		22.18		2.81		42.67		21.38		10.96
59	Salsola pestifer (Russian Thistle)	June 4, 1928	Pre-flowering		13.71		2.08		46.98		12.00		25.23
60	Salsola pestifer (Russian Thistle)	Aug. 12, 1927	Early flowering	20.22		1.85		34.99		20.59		22.36	
61	Homalobus caespitosus (Dwarf Pea)	May 23, 1928	Flowering		16.59		2.61		41.06		31.28		8.46
62	Homalobus tenellus (Dwarf White Pea)	May 23, 1928	Flowering		15.66		2.59		39.50		33.11		9.14
63	Astragalus sp. (Purple vetch)	May 24, 1928	Flowering		21.52		2.70		46.21		20.45		9.12
64	Gutierrezia Sarothrae (Brown Weed)	May 25, 1928	Pre-flowering		19.40		4.10		51.81		13.82		10.87
65	Diholcos bisulcatus (Bushy purple pea)	May 27, 1928	Early flowering		9.39		2.82		43.86		24.02		9.91
66	Artemisia cana (Sage Brush)	May 22, 1928	Pre-flowering		18.31		6.86		43.31		23.20		8.32
67	Artemisia cana (Sage Brush)	Aug. 10, 1927	Flowering	12.15		6.85		44.48		29.69		6.89	
68	Artemisia cana (Sage Brush)	Nov. 1, 1927	Cured	8.40		4.24		47.37		35.42		4.57	
69	Artemisia frigida (Prairie Sage)	May 30, 1928	Pre-flowering		14.77		5.79		42.94		28.09		8.41
70	Artemisia frigida (Prairie Sage)	Aug. 10, 1927	Flowering	7.78		4.41		45.57		37.81		4.43	
71	Artemisia frigida (Prairie Sage)	Sept. 25, 1927	Late flowering	11.37		6.64		44.08		30.13		7.78	
72	Artemisia frigida (Prairie Sage)	Nov. 1, 1927	Cured	4.81		3.07		46.08		42.40		3.64	
73	Psoralea lanceolata (Sand Vetch)	June 24, 1928	Flowering		15.79		6.94		49.62		21.14		6.51
74	Dondia depressa (Sea blite)	May 25, 1928	Pre-flowering		29.39		3.37		25.71		9.79		31.74
75	Ctenophyllum pectinatum (Bushy White Pea)	May 22, 1928	Flowering		24.22		3.17		41.17		23.37		8.07
76	Astragalus sp.(Decumbent White Pea)	May 30, 1928	Early flowering		14.62		3.32		46.17		30.18		5.71
77	Astragalus sp. (Decumbent Purple Pea)	May 27, 1928	Flowering		19.87		1.61		43.59		22.46		12.47
78	Tium Drummondii (Silver Pea)	May 27, 1928	Flowering		28.43		2.58		38.98		21.02		8.99
79	Eurotia lanata (Silver Sage)	May 30, 1928	Pre-flowering		19.47		2.21		32.24		29.47		16.61
80	Eurotia lanata (Silver Sage)	Aug. 10, 1927	Late flowering	14.23		2.17		38.74		31.51		13.35	
81	Atriplex Nuttallii (Salt Sage)	May 25, 1928	Pre-flowering		20.84		2.49		39.69		13.04		23.94
82	Atriplex Nuttallii (Salt Sage)	Aug. 10, 1927	Flowering	14.18		2.15		42.43		22.40		18.84	

It will be observed that the crude protein content varied from 9.80 to 29.66 per cent; the total ash from 7.68 to 17.88 per cent and the nitrogen-free extract from 38.03 to 51.88 per cent. The yield of dry matter varied from 261 to 4031 lbs. These workers conclude that the poorer pastures not only yield less grass but that the grass is inferior in quality to that secured on the better pastures. Grass samples were collected also by means of plucking in such a manner as to simulate grazing by a cow. These samples were analyzed and their chemical composition closely approximated that of the grass clippings. These workers conclude also that grass kept in the vegetative stage by clipping or grazing, exhibits a fair degree of uniformity in chemical composition throughout the season. This is in accordance with the findings of Stapledon (*14*) while Archibald and Nelson (*1*) claim that seasonal differences of rainfall, temperature and sunshine may markedly affect the chemical composition.

In the investigations herein reported the principal species were collected separately by clipping pure stands or individual plants. Chief attention was given to the stage of growth rather than to the date of collection. In the case of a few of the more common species which make up the great bulk of the vegetation, collections were made during several growth stages, and also late in the fall and again early in the spring before new growth started. Care was taken to exclude all old growth and to clip the plants as close as a cow would graze them. The samples were air dried and then sent to the Division of Chemistry at Ottawa for chemical analysis.

Only a few samples were collected in 1927 and the analyses of these have already been reported upon by Dr. Shutt, Dominion Chemist (*13*). During 1928 additional samples were collected and analyzed. The analyses of all samples collected during these two years are presented in table 3.

It will be observed that most of the species have a high protein content while in the early growth stages and at this time they should be regarded as concentrates rather than as roughages. As the plants approach maturity and become cured there is a marked decrease in their protein content and a further decrease takes place on exposure to winter conditions. A few examples taken from the 1928 results are presented in table 4.

As most of these species are relished by livestock they play an important rôle as pasture plants. It will be noticed too that the Artemisias have a high crude fat content (see table 3).

During 1929, over two hundred samples were collected, but the analyses have not yet been completed. A number of different sites have been selected representing different soil and climatic conditions. Samples will be collected from each of these sites and the effects of the physical controls on the chemical composition determined. In subsequent analyses the lime and phosphoric acid content will be determined. The purpose of the study is to determine the nutritive value of each species in all of its principal growth stages and as grown under different environmental conditions.

TABLE 4. *Protein content of certain grass species as collected in different growth stages.*

Name of Species	Pre-flowering Stage	Flowering Stage	Seed Stage	Cured	After Winter Exposure
Stipa comata	14.51	.....	8.60	4.91	2.83
Koeleria gracilis	15.53	9.72	8.20	.....	2.29
Agropyron Smithii	16.44	15.86	.....	3.33	2.53
Bouteloua gracilis	.....	11.54	8.09	3.33	2.87
Pao laevigata	13.84			.....	2.47
Distichlis stricta	15.43	.....	.....	.....	3.43

Many of the broad leaved species have high protein and ash contents, as shown by the following examples:

Species	Stage of Growth	Protein content	Total Ash content
Eurotia lanata	Pre-flowering	19.47	16.61
Atriplex Nuttallii	"	20.84	23.94
Artemisia cana	"	18.31	8.32
Artemisia frigida	"	14.77	8.41
Salsola pestifer	"	13.71	25.23
Ctenophyllum pectinatum	Flowering	24.22	8.07
Tium Drummondii	"	28.43	8.99

3. *Plant Succession*

Plant succession is being studied chiefly to determine the changes brought about by different treatments and grazing practices, and the methods employed vary according to the purpose of the study. The kinds of plots used are as follows:

(1) Permanent, list quadrats. These are permanently staked out and vary in size from one square meter to 100 square meters. This kind of quadrat is used when the purpose of the study is to determine the increase or decrease of a few species only. A record is kept of the number of plants of each of these species, of the number of culms, or of the area covered, and of the height, vigour, and seed production of the plants. On a piece of squared paper a rough map is made, showing the position on the quadrat of the individual plants of each species under observation.

(2) Permanent, charted quadrats. These are permanently staked and have an area of one square meter each. Mapping is done by the aid of a pantograph (Figure 4). It takes two to operate this instrument, one to move the pointer around the plants and to call out the name of each plant, and another to mark the names on the map. By this method, mapping can be done quickly and accurately. The maps are 1/16 of 1 square meter in size or approximately 10 inches square. They show the position and area covered by each shoot or clump of vegetation on the quadrat. Seedlings are indicated by means of points. Symbols are used in accordance with the method outlined by Clement (*5*). Mapping is done at intervals of two or three years and even very minute changes in the vegetal cover can be detected and measured accurately. Notes are taken also on the height and density

Figure 4. Charting a quadrat. A frame with cross wires is used now in place of the one shown. The map is one-sixteenth of the size of the quadrat or approximately 10 inches square.

of the principal species, on seed production, and on such influencing factors as location, altitude, slope, exposure, soil type, distance from watering places, salting places, paths, gates, etc., injury done by rodents or insects and nature of vegetation on the surrounding area. On Form 1 is presented the data concerning quadrat No. C—81, mapped in 1929, and in Figure 5 is shown the map of this quadrat.

Form 1.

QUADRAT No. C-81

1. Date Charted—Sept. 19, 1929.
2. Location—Sec. 15, N.E. 30 yards from fence and 50 yards N. E. of fence brace.
3. Character of Site—(a) Elevation—Open prairie, 3000 feet.
   (b) Exposure and slope—East slope of 4 degrees.
   (c) Soil—Sandy loam.
4. Plant Type—(a) Principal species on surrounding area—Bou. St. Kol. Ag. A.f. Eu. 1. Gut. S.d.
   (b) Density of vegetative cover—A fair cover, large patches of Bou.
   (c) Height of vegetation—Bou. 1"-3". St. 5"-10". Kol. 4"-8".
   (d) Seed production—A small amount of St. Kol. and of weeds. Bou. and Ag. will not produce seed this year.
5. Summary of Quadrat Data—
   (a) Grasses—

Symbol	Bou	St.	Kol.	Ag.	Totals
Number of specimens	12	52	1	1	66
Area occupied sq. cm	2612	784	38	16	3450
" " %	26.12	7.84	.38	.16	34.50

(b) Broad Leaved Plants—

Symbol	A.f.	Gut.	Eu. 1.	Totals
Number of specimens	12	1	4	17
Area occupied sq. cm.	464	76	78	618
" " %	4.64	.76	.78	6.18

6. Relative Forage Value of Quadrat.....

7. Distance of Quadrat from nearest watering place—½ mile.

8. Remarks—Bou.—*Bouteloua gracilis.* St.—*Stipa comata.* Kol.—*Koeleria gracilis.* Ag.—*Agropyron Smithii.* A.f.—*Artemisia frigida.* ..Gut.—*Gutierrezia sarothrae.* Eu. 1.—*Eurotia lanata.* S.d.—*Selaginella densa.*

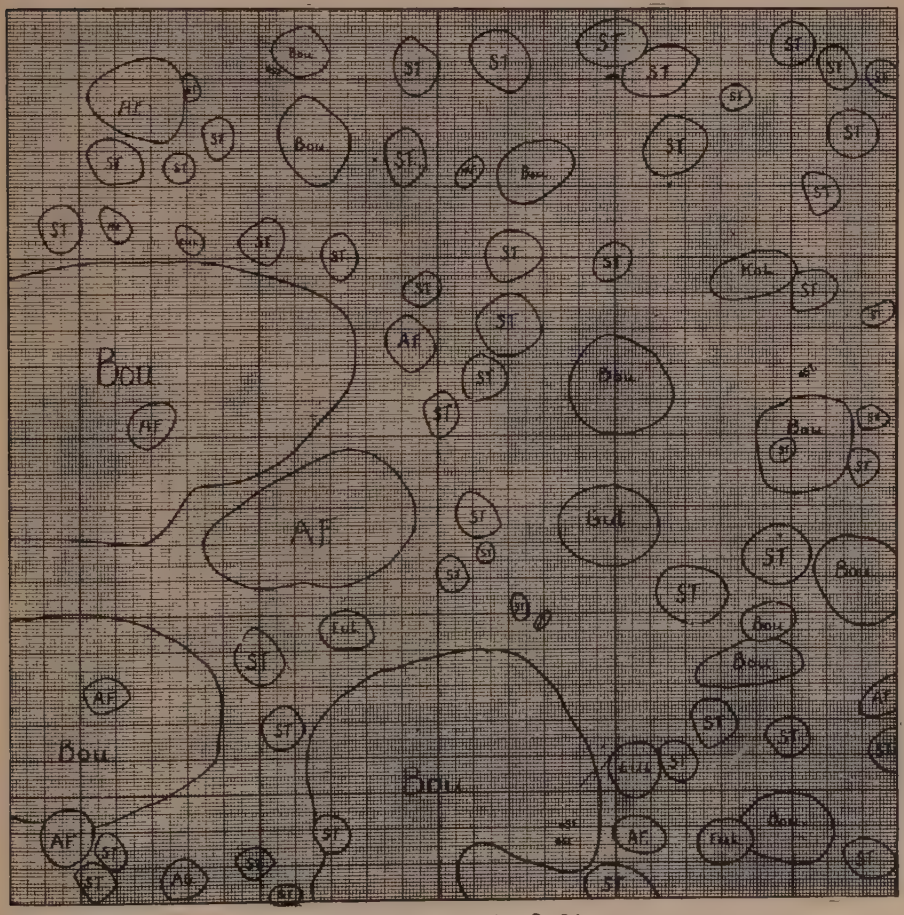

Fig. 5. Map of Quadrat No. C-81.

Figure 6. Range cattle on overgrazed pasture in southeastern Alberta. The light coloured weed, Prairie Sage, (*Artemisia frigida*), has largely taken the place of valuable grasses.

(3) Permanent, mapped and listed quadrats. These have an area of one square meter each. A frame divided into square decimeters is used, thus each division equals one per cent of a square meter. On a form, there is tabulated the name of each species found on the quadrat, the number of plants of each species and the area in per cent occupied by each species. On a piece of squared paper a free-hand sketch is made, showing the location of each of the principal species on the quadrat.

(4) Permanent, mapped and listed transects. These are essentially the same as mapped and listed quadrats, except in size and shape. In width they vary from one to four decimeters and in length from one to several meters according to the length required for the inclusion of such environmental conditions and vegetative species as are to be studied. Transects are used both alone and in conjunction with quadrats, and are of great value in studying the correlation of environmental factors and vegetal types, and in the study of plant migration.

Quadrats and transects have been established on areas that are representative of different soil and climatic conditions, and on pastures that are being given various treatments and subjected to different grazing practices such as, (a) total protection, (b) continuous summer grazing, (c) deferred and rotational grazing, (d) early spring grazing, (e) late fall grazing and (f) summer grazing with protection during the spring months.

A study has been made of certain areas that have similar soil and climatic conditions, but which have been subjected to different grazing practices. For instance, some of these pastures had been grazed closely from early spring until late in the fall, some had been protected during a part of the summer and others had been grazed during the winter months only. From such studies it is evident that when a pasture is over-grazed, certain species such as *Stipa comata, Koeleria gracilis* and some of the Poas are the first to drop out. This is probably due to the fact that these are tuft grasses and

that they make a very early spring growth, and therefore are more closely grazed while in the early leaf stage than are other species such as *Agropyron Smithii, Muhlenbergia cuspidata* and *Bouteloua gracilis*. As the grasses disappear unpalatable deep-rooted weeds take their place and such weeds are indicators either of wrong grazing practices or of other changes in the habitat. As the grasses are killed out there is more moisture for the weeds which being unpalatable are allowed to flourish and produce much seed, thus adding to the weed infestation.

While every species may be regarded as an indicator there are two species that are outstanding in this respect. One is *Gutierrezia sarothrae,* commonly called "Brown Weed" which is most prevalent on heavy clay soils, on silt covered areas and on partly eroded areas. This weed has a long tap root, it matures rather late in the season and is seldom eaten by livestock. Large areas of range lands are covered with an Agropyron-Gutierrezia associes. The other outstanding weed indicator is *Artemisia frigida,*—commonly called Wormwood or Prairie Sage. This ubiquitous weed is most prevalent on loam or sandy loam soils. It is seldom eaten by cattle and sparingly by sheep, except during the winter months at which time the plants are not injured by grazing. Due to overgrazing, large areas are dominated by this weed. (See Figure 6).

Other common weeds that are indicators of overgrazing or of other unfavourable conditions are, *Opuntia polyacantha* (Cactus) *Artemisia cana* (Sage Brush) *A. gnaphaloides* (Dwarf Sage Brush) *Selaginella densa,* (Little club-moss) *Paronychia sessiliflora* (Whitlow-wort) *Sideranthus spinulosus* (Iron Weed) *Hymenoxys Macounii* (Colorado Rubber Plant) *Eriogonum flavum* (Umbrella Plant) and *Chrysopsis villosa* (Golden Aster).

The Effects of Different Grazing Practices Upon the Vegetative Cover.

Chapline (*4*) speaking of the "Range Research of the United States Forest Service" states, "The research has clearly indicated that the satisfactory use of range forage offers the greatest possibilities for developing more efficient production, decreasing costs, and increasing profits in the range livestock business," and again "The productivity of national forest ranges has increased about 25 per cent in the last 15 to 20 years through regulation and the application of improved principles developed by research. On the other hand, most other range areas have continued to decline until on the average, they are at least 50 per cent below their producing possibilities."

Sampson (*12*) has shown that grasses not grazed until they have made considerable growth, produce much more forage annually than when grazed in the early leaf stage. Other workers have found that plants that have been allowed to develop considerable leafage, go into winter with much more starch stored in their roots than do plants that have been kept closely grazed throughout the summer and fall months. In other words, a sound grazing practice takes into account the characteristics and requirements of the different species that make up the vegetal cover of the pastures.

Unfortunately, during the past, very little attention has been given to the study of our native pasture plants, and the fundamental principles of

good pasture management have been largely disregarded. The practice followed by most of our ranchers is to conserve a portion of the range for winter grazing and to graze the remainder closely from early in the spring until late in the fall. The plants are injured by close grazing and excessive tramping during the spring months and overgrazing during the summer and fall prevents seed production and causes the plants to go into winter in a weakened condition. The result is that large areas of our range lands are much below their maximum carrying capacity.

At the Dominion Range Experimental Station several different grazing practices are being tested. These include, (1) continuous summer grazing, (2) continuous summer grazing with different periods of protection during the spring and early summer months, (3) deferred and rotational grazing and (4) seasonal grazing.

In testing and comparing these various methods of grazing it is essential that we be able to detect and measure any changes that take place in the vegetative cover of the pastures from year to year. A casual inspection of the pastures is not enough, nor are the gains made by livestock a reliable criterion. Leppan (*11*) and other investigators have found that changes in the vegetal covering, tending towards either improvement or depletion, may take place for a considerable length of time and to quite a marked extent before being noticed in a mere general inspection of the pastures.

The changes that take place in the vegetative cover are being studied by means of quadrats as described under 'Plant Succession'. Permanent, charted quadrats and mapped and listed quadrats are used mostly for this purpose. A large number of these quadrats have been established in each field. Figure 5 shows the map of quadrant C--81 and in Form 1 is presented the data concerning this quadrat. It will be observed that 34.50 per cent of the area is covered with grass, chiefly *Bouteloua gracilis,* and 6.18 per cent with weeds of which *Artemisia frigida* is the most prevalent. Thus, 40.68 per cent of the area of this quadrat is covered with vegetation, while 59.32 per cent is bare ground. Such factors as nutritive index, yield index, relative forage value, and maximum percentage of cover are being studied but must await further investigation.

As a large number of quadrats located on representative areas are being studied, the nature of the changes that take place on them can be taken as a criterion of the changes that take place on the field as a whole. The changes that take place in the vegetal covering from year to year, tending towards either improvement or depletion can be detected and measured. This will make possible the determination of the productivity and carrying capacity of the pastures, and a comparison of different grazing practices, as regards their effects upon the vegetative cover.

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A SERIOUS CASE OF DWARFING AND MALFORMATION OF NARCISSUS (*Soleil d'or*)

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[Received for publication April 10, 1930].

A florist who had planted a hundred and forty thousand Soleil d'or narcissus bulbs for the cut flower trade (winter of 1929-30) complained that about fifty per cent of the flowers produced from these bulbs were unfit for sale on account of dwarfing, malformation and brown spot discolouration of the stems and foliage. Wishing to ascertain the cause of the trouble he submitted to us, near the end of the season, a flat containing forty bulbs in flower.

Figure 1. Flat of soleil d'or narcissi, showing some of the plants to be stunted.

The general appearance of the plants as received is shown in Figure 1, except that six of the best stalks had been cut and removed prior to the photograph being taken. The dwarfed condition of some of the flowers is evidenced in the picture. A few such deformed plants were found scattered indiscriminately throughout the mass.

The bulbs had evidently been emptied into the box in any order when planted, covered with soil and kept watered in the greenhouse until submitted to us for examination.

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Figure 2. Three specimens removed from flat shown in figure 1:
A. Normal healthy plant, well developed in root, stem and foliage; one fine flower stalk cut away. Below is a section of the bulb showing all white tissue with no brown markings.
B. Abnormal plant with poor root, dwarfed flower stalk and distorted foliage. There was a number of brown spots on the foliage which do not show in photo. Beneath is a section of the bulb showing brown markings of dead tissue in leaves of bulb.
C. Plant showing very meagre development both of root and top. No flower stalk at all.

Results of Examination

All plants were carefully removed from the flat and the soil washed from the bulbs and roots.

Tops—It was then found that twenty-eight bulbs had produced normal, healthy, upstanding stalks, flowers and leaves without any markings or disfigurements, that twelve bulbs had produced flower stalks and leaves that were stunted and malformed, and some of these had brown and yellow markings on them in various places.

Two of the bulbs had produced no flower stalks at all, and one of these had only two inches and the other only six inches of leaf growth. The leaves in both cases were sickly looking with brown tips and yellow and brown markings lower down, more particularly on the edges of the leaves.

Roots—The root growth on the twenty-eight normal specimens was plentiful, white and vigorous looking, while the rootgrowth on the twelve stunted specimens was meagre, with some of the rootlets flaccid and discoloured brown, and in some cases these were dead.

Bulbs—Sections cut from the bulbs that had produced the healthy tops showed them to be white and firm all through, without any brown rings or markings.

Sections cut from the twelve bulbs that had produced the stunted and deformed tops, showed brown rings and brown areas of various sizes in the bulb tissue. The brown discoloured tissue of which these markings were composed, was dead and decaying.

Cause of the Trouble—The lesions and disfigurements described above appear to be identical with those reported by C. E. Scott (*1*) et al., as being caused by *Tylenchus dipsaci* Kuhn (Bastian). A careful search for this nematode was made in numerous microscope preparations made from the diseased tissue taken from the bulbs, stalks and leaves. Not a single specimen of the nematode, however, was found in any preparation.

Both fungous mycelium and various species of bacteria were found in the brown areas of the bulbs that were in immediate contact with the surface. These, however, were considered to be secondary invaders of the dead tissue rather than the cause of the trouble, as they could not be found in the brown, discoloured tissue in the interior of the bulb or stalk, unless these were badly rotted, nor could they be found in the brown and yellow spots of various sizes occurring on the leaves and stalks.

The disease did not appear to be progressive while under observation, as it would have been had it been caused by bacteria or fungi.

Conclusions

1. No fungous or bacteria could be found to be the cause of the disease,
2. The disease was not noticeably progressive,
3. The disease lesions were characteristic of those caused by *Tylenchus dipsaci* Kuhn (Bastian).

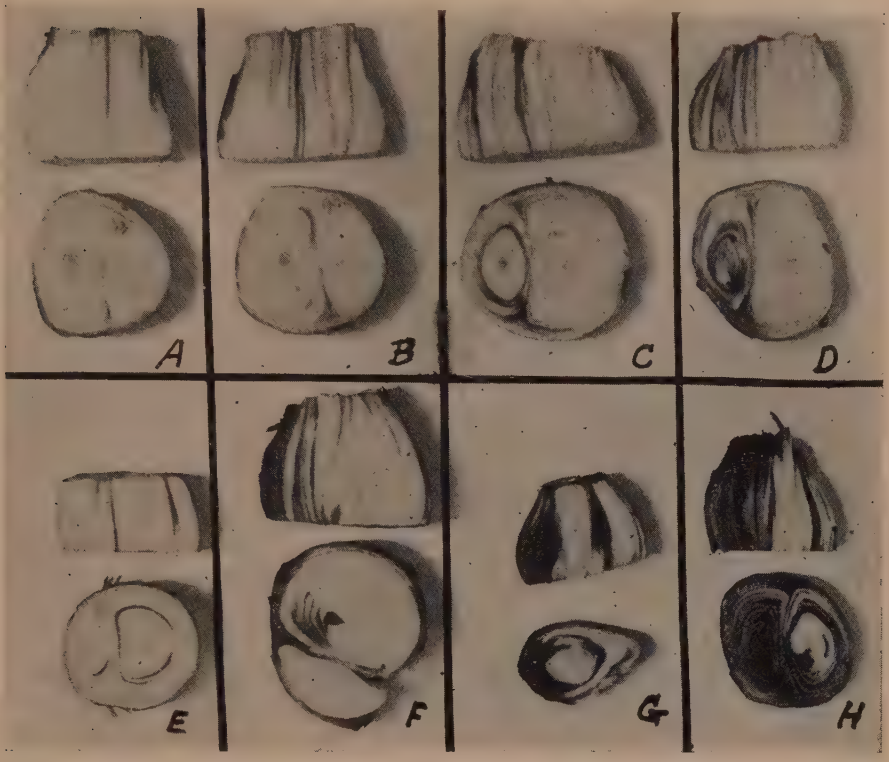

Figure 3. Cross and longitudinal sections of eight bulbs taken from flat shown in figure 1. A was a sound, healthy bulb, showing no brown markings and having produced a well grown top; B, C, D, E and F were bulbs that had produced dwarfed and malformed tops that were unsaleable; G and H, which were very badly diseased, had produced no flower stalks and scarcely any roots or leaves.

4. None of these nematodes could be found in any of the diseased tissues,—

Therefore it would appear probable that the bulbs producing the diseased plants had been infested with the nematode *Tylenchus dipsaci* Kuhn, when growing in the field, that after being harvested the bulbs had been treated in some way to destroy the nematodes present in the bulb and that the injury done to the bulbs by the nematodes before they were destroyed was responsible for the abnormal appearance of the flower stalks and leaves and for the brown markings and decayed areas inside the bulbs.

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A SUMMARY OF INSECT CONDITIONS IN CANADA IN 1929*

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[Received for publication April 8, 1930].

The Dominion Entomological Branch maintains, under the direction of the Dominion Entomologist, an Insect Pest Survey with the object of collecting information regarding the occurrence, distribution, seasonal prevalence, hosts and economic importance of the many species comprising the large and varied injurious insect fauna in the Dominion.

As is commonly known, insect species fluctuate markedly in numbers and importance from year to year. The information collected by the survey is of value not only in arriving at a correct estimate of the relative importance of the different species, but by correlating it with such natural phenomena as climate, weather conditions and biological control agencies, it is also of value in securing a better understanding of the factors governing insect fluctuations and distribution.

One of the outcomes of the survey is the preparation of the Canadian Insect Pest Review at monthly intervals during the season of insect activity. This is a mimeographed publication made available to entomological workers throughout the country. As this publication is limited in circulation to those primally interested in entomology, it has been considered desirable to prepare for more general distribution a summarized report dealing briefly with the more important insects during the past year. The summary presented herewith has been prepared from a careful study of the numerous reports received in connection with the Insect Pest Survey from officers of the Entomological Branch and others engaged in entomological studies in the various provinces.

The season of 1929 was characterized over the greater part of the Dominion by a cool, backward spring, followed by an exceptionally dry summer, and generally speaking the country as a whole was comparatively free from serious insect outbreaks.

Weather conditions were favourable to grasshoppers, and these insects increased markedly over a considerable part of Canada, particularly in the dry cattle range areas of British Columbia and in sections of the Prairie Provinces. They were not abundant enough, however, to cause serious crop damage.

Moderate outbreaks of cutworms occurred in sections of New Brunswick, southern Ontario and the Prairie Provinces, but damage by these insects was not considered excessive. The estimated loss to field crops, however, in 1929, in Saskatchewan alone, due to cutworm depredations, was placed at nearly one and one-third million dollars.‡ This serves to illustrate the important damage done by these insects even in years of moderate abundance.

Depredations by wireworms were reported from parts of Ontario, the Prairie Provinces and British Columbia, but severe crop damage was noted

*Prepared by direction of the Dominion Entomologist.
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‡This and other estimates of crop damage by insects in Saskatchewan, were prepared by Mr. K. M. King, Dominion Entomological Laboratory, Saskatoon, in coöperation with the Statistics Branch of the Saskatchewan Department of Agriculture.

only in Saskatchewan and certain dry sections of Alberta and in the Okanagan valley, British Columbia. The loss to grain and other field crops in Saskatchewan, due to wireworms, was estimated at approximately three and one-sixth million dollars. In the Okanagan valley, British Columbia, serious damage occurred, notably to onions and tobacco.

Except locally in southern Quebec, white grubs were not responsible for serious crop injury in the Dominion. Flights of June beetles were reported from localized areas in New Brunswick, southern Ontario and tree-grown sections of Manitoba.

In Ontario the European corn borer, *Pyrausta nubilalis* Hbn., in general again showed a decrease in the area in which compulsory control is being enforced, clear decreases being determined in sixteen counties. In the counties of Essex and Kent, formerly the most severely affected, although the stalk infestation was lower, the number of borers was probably about the same as in the previous year. The infestation increased somewhat in eight other counties. In five counties outside the control area the infestation was low, the number of borers remaining about the same as in 1928. An interesting point noted was the apparent quite rapid increase of the borer on Manitoulin island. In Quebec, although not carefully surveyed, the infestation on the average is considered to have remained about the same as in 1928. In New Brunswick, the infestation is still present. No sign of the borer was found in the localities infested in 1928, but it was discovered in very small numbers in other localities in Sunbury, Queens and Charlotte counties. The borer also was discovered, in very small numbers, for the first time, in Nova Scotia, in the counties of Kings, Annapolis, Digby and Yarmouth, and from the stage of development is presumed to be of the two-generation strain of this species.

The Colorado potato beetle, *Leptinotarsa decemlineata* Say, was about normal in Eastern Canada, and less abundant and destructive than usual throughout the West. In British Columbia it occurs only in the extreme southeastern corner of the province, in the East Kootenays and the Creston district, where its spread west and north is retarded by natural barriers and control practices.

The onion magot, *Hylemyia antiqua* Mgn., appreciably increased over previous years in Manitoba and Saskatchewan, and the cabbage maggot *H. brassicae* Bouche, was more destructive than usual in the Okanagan valley, British Columbia. Elsewhere in the Dominion, root maggots were not more than normally injurious.

The imported cabbage worm, *Pieris rapae* L., occurred in about its usual abundance throughout Eastern Canada. During the latter part of the season, it caused considerable damage to cruciferous crops in southern sections of the Prairie Provinces. Light infestations were noted in the Rainy River district and north of Lake Superior and Lake Huron, Ontario, and in Manitoba, north of latitude 52.

The dry season engendered increased crop damage by the wheat stem sawfly, *Cephus cinctus* Nort., in sections of the Prairie Provinces. The loss to wheat in Saskatchewan in 1929, due to the sawfly, was estimated at five

and one-half million dollars. The area of greatest damage occurred over the south-central part of the province. The sawfly also caused noticeable damage in western Manitoba, and in certain localized areas in Alberta where owing to the failure of the native grass crop, due to the dry spring, it concentrated its attacks on wheat. Given favourable weather conditions a further increase of the insect in 1930 is anticipated.

There was an unusually severe outbreak of tarnished plant bug, *Lygus pratensis* L., in Ontario, affecting a variety of garden plants, including celery, which was badly damaged in certain localities. This pest was also very troublesome in southern Quebec. In the Okanagan valley, British Columbia, it caused damage to orchard cover crops and injury to apple blossom buds.

Several species of flea-beetles were abundant on a variety of field and garden plants in sections of the Maritime Provinces, southern Quebec, Ontario and southern British Columbia, causing considerable damage.

A moderate outbreak of the zebra caterpillar, *Ceramica picta* Harr., occurred in parts of New Brunswick, Quebec and Ontario, affecting cruciferous crops and other vegetable and flowering plants in the latter part of the summer.

An infestation of the pea weevil, *Mylabris pisorum* L., was discovered for the first time on Vancouver Island, British Columbia, late in 1929. Efforts are being made to eradicate the insect which so far has not been a pest in the province.

Slight infestations of the Mexican bean beetle, *Epilachna corrupta* Muls., were found in three localities in southern Ontario. This species spread northward through the eastern United States from Alabama, during the past decade, and was first discovered in Ontario, in 1927. The original infestations disappeared and it appears extremely likely that climatic conditions will prevent the insect from becoming a pest in Canada.

Aphids of several species were abundant and injurious on a variety of trees, shrubs and field and garden plants in many parts of Canada. Cabbage and turnip aphids were conspicuous among those attacking field and garden crops, and the green apple aphis, *Aphis pomi* DeG., was the most important species in fruit-growing sections, assuming outbreak proportions in parts of the Maritime Provinces, southern Quebec, Ontario and British Columbia.

The plum curculio, *Conotrachelus nenuphar* Hbst., was a serious pest in fruit-growing sections of Eastern Canada, affecting apples, plums, cherries and peaches. The apple curculio, *Tachypterellus quadrigibous* Say, was particularly abundant in orchards of southern Quebec, and occurred for the first time as a fruit pest in British Columbia, causing severe damage to pears in the Salmon Arm district.

The codling moth, *Carpocapsa pomonella* L., appeared to be less than normally abundant in eastern sections of Canada. In the west, this species is increasing in the Okanagan valley and on Vancouver Island, British Columbia.

Severe outbreaks of the apple maggot, *Rhagoletis pomonella* Walsh., developed in sections of New Brunswick and Ontario where it is an important pest. Reports from the latter province indicate that the insect was largely controlled by spraying.

The lesser apple worm, *Laspeyresia prunivora* Walsh., showed considerable increase over previous years locally in New Brunswick, and was responsible for much fruit injury in the Okanagan valley, British Columbia.

The oriental peach moth, *Laspeyresia molesta* Busck., increased markedly in southern Ontario and caused serious loss in the Niagara district, particularly east of St. Catharines. This insect was first discovered in Canada, in October, 1925, in the above district.

Budmoths were less abundant in Nova Scotia orchards than for some years past, but appear to be on the increase in southern sections of New Brunswick, Quebec and Ontario.

The white-marked and rusty tussock moths, *Hemerocampa leucostigma* S. & A., and *Notolophus antiqua* L., caused considerable damage in Nova Scotia apple orchards by boring deep holes in the fruit. The former species which also attacks shade and forest trees, was prevalent over a considerable part of Eastern Canada and appears to be increasing.

The cigar case-bearer, *Haploptilia fletcherella* Fern., was conspicuous in sections of the Maritime Provinces and Ontario, particularly in neglected apple orchards. The pistol case-bearer, *H. malivorella* Riley, was abundant in uncared for orchards in the Annapolis valley, Nova Scotia.

The apple and thorn skeletonizer, *Hemerophila pariana* Clerck., was widespread in the Annapolis valley, Nova Scotia, and was recorded for the first time in Ontario, in neglected apple orchards of the Niagara peninsula. It is not known to occur elsewhere in Canada, and so far, is not regarded as a serious pest.

The oyster shell scale, *Lepidosaphes ulmi* L., appears to be on the increase in sections of New Brunswick and southern Ontario, and is becoming a serious pest in the interior of British Columbia. It attacks a variety of orchard, shade and forest trees and shrubs.

Spider mites were prevalent in many parts of Canada. The European red mite, *Paratetranychus pilosus* C. & F., for the first time was an important pest in orchards of southern New Brunswick, and was abundant and injurious on plum, apple and peach in the Niagara district, Ontario. Red spiders also heavily infested small fruits and various other plants in sections of Ontario and the Prairie Provinces, and fruit trees in the Okanagan valley, British Columbia.

An outbreak of spruce budworm, *Cacoecia fumiferana* Clem., on balsam, in the Westree district, north of the Georgian Bay, Ontario, which apparently originated around Meteor lake, is slowly extending westward. The outbreak of this species on Vancouver Island, British Columbia, north of Victoria, is subsiding, but considerable defoliation was done to Douglas fir.

The black-headed budworm, *Peronea variana* Fern., occurred in outbreak form for the first time in Eastern Canada, in southern Cape Breton Island, Nova Scotia, and caused severe defoliation of balsam and spruce.

Tent caterpillars, *Malacosoma* spp., were unusually abundant on Vancouver Island and in the Lower Fraser valley, British Columbia, in the early part of the season, severely defoliating extensive areas of deciduous trees

and shrubs. They also caused much foliage injury to native bluffs and plantations in sections of Alberta and Saskatchewan.

The fir sawfly, *Neodiprion abietis* Harr., was found infesting a considerable area of balsam forest in the Sault Ste. Marie district, Ontario. An outbreak of this insect in Manitoba has been much reduced by parasites. An incipient outbreak of a species of sawfly, of the same genus as the above, has been discovered affecting jackpine over a considerable area in the Biscotasing district, Ontario. Severe local outbreaks of this insect also were found in Quebec.

The fall webworm, *Hyphantria cunea* Dru., was widespread and abundant in the Maritime Provinces, Ontario, and the Lower Fraser valley, British Columbia, affecting orchard, forest and shade trees and shrubs.

Outbreaks of the satin moth, *Stilpnotia salicis* L., in the Lower Fraser valley, British Columbia, resulted in severe defoliation of poplars and willows. The satin moth is a European species, first recorded in Canada at New Westminster, B.C., in 1920. It now occurs throughout the lower Fraser valley and on the east coast of Vancouver Island.

The European beech bark louse, *Cryptococcus fagi* Baerns., which occurs widely in Prince Edward Island and Nova Scotia, is spreading northward in eastern New Brunswick from the infested area in Albert and Westmoreland counties. It was first discovered in New Brunswick in 1927.

The brown tail moth, *Nygmia phaeorrhoea* Don., which is an important pest of orchard, shade and forest trees, has been practically eliminated from Canada. The only evidence of the pest found since 1927, in the previously infested areas in the Maritime Provinces, being a male moth captured at Fredericton in July, 1929.

An outbreak of the hemlock looper, *Ellopia fiscellaria* Gn., in Quebec, which was severe along the north shore of the St. Lawrence between the Bersimis and Pentecote rivers, in 1928, declined markedly during 1929. There are localized outbreaks of the looper on Vancouver Island, B.C., and the adjacent mainland.

Leaf-mining insects of several species were conspicuous on a variety of forest and ornamental trees and shrubs in various parts of the Dominion.

Infestations of the gypsy moth, *Porthetria dispar* L., discovered in southern Quebec in 1924, in Stanstead and St. Johns counties, appear to have been completely stamped out by the vigorous combative measures adopted. Extensive scouting, continued in 1929, failed to reveal any evidences of the pest.

During the summer, mosquitoes, in general, were decidedly less abundant throughout Canada than normally, no doubt largely owing to the exceptionally dry season. This condition was modified in some sections by river floods in spring, which gave rise to local outbreaks.

An unusual abundance of wasps, hornets and bees was reported from sections of Nova Scotia, southern Quebec and British Columbia. Ants also were very troublesome about lawns and houses in southern British Columbia.

LA COMPOSITION MOYENNE DU LAIT DE LA VACHE CANADIENNE

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Nous avons cru bon, dans l'intérêt de l'industrie laitière en général, et de la race bovine Canadienne en particulier, d'établir, par l'analyse chimique, la composition moyenne du lait de cette dernière race, comme cette analyse existe déjà pour les autres races laitières.

Ce travail long et minutieux, fait avec toutes les précautions possibles, a donné les chiffres suivants:

Poids spécifique à 60° Fahr.	1032.4
Eau	86.49%
Matière grasse	4.55
Protéines totales	3.70
Lactose	4.29
Cendres	.77
Non dosé	.20
Solides totaux	13.31
" non gras	8.76

Il est à remarquer que ces chiffres sont le résultat de 71 analyses qui ont été faites à différents temps de l'année, à partir du mois de juin 1929, jusqu'à date, de manière à couvrir autant que possible les différentes périodes de la lactation, de manière à couvrir également les différentes phases de l'alimentation, au pâturage, à l'étable et à l'alimentation mixte.

Le travail a été fait sur des échantillons prélevés chez quelques éleveurs dont l'honnêteté et la bonne foi ne peuvent être mises en doute. Ils comprennent une partie de la traite du soir et une partie de la traite du matin, mélangées ensemble. Tous les dosages ont été faits en duplicata et avec le plus grand soin possible.

Au sujet de la matière grasse, je dois dire que nous avons fait 3 épreuves différentes, chacune en duplicata. Ces épreuves sont: l'analyse chimique, par extraction à l'éther; la méthode Babcock, celle qui est la plus généralement employée et qui d'ailleurs est reconnue comme officielle; et la méthode Babcock avec lecture en se servant de glymol (une huile à densité plus faible que la matière grasse du lait). Les chiffres cités représentent la moyenne de ces trois épreuves.

Il ne fait aucun doute que si nous avions pris simplement la lecture au Babcock ordinaire, nous serions arrivés à un chiffre nettement supérieur à celui que nous avons obtenu. Nous avons cru procéder de cette manière, afin d'avoir des chiffres aussi précis et aussi impartiaux que possible.

En résumé, nous croyons que les moyennes que nous avons obtenues représentent parfaitement bien la composition moyenne du lait de la vache canadienne-française. Si, maintenant, nous faisons une comparaison avec les résultats obtenus par l'analyse du lait des autres races laitières, nous voyons que la race canadienne arrive en troisième, c'est-à-dire, immédiatement après la Jersey et la Guernesey. C'est ce qui ressort des chiffres cités au tableau suivant:

Composition moyenne du lait des vaches de différentes races.

Race	Poids spécifique	Eau %	Matière grasse %	Protéines totales %	Lactose %	Cendres %	Solides totaux %	Nombre d'épreuves
Jersey	——	85.10	5.25	3.92	4.98	.75	14.90	8
Guernesey	——	85.57	4.96	3.78	4.94	.75	14.43	5
Canadienne	1032.4	86.49	4.55	3.70	4.29	.77	13.31	71
Ayrshire	——	87.18	3.64	3.38	5.13	.67	12.82	9
Shorthorn	——	87.55	3.65	3.27	4.80	.73	12.45	3
Holstein	——	87.71	3.51	3.22	4.89	.67	12.29	6

En étudiant les chiffres de ce tableau, nous voyons que la matière grasse, les protéines, les solides totaux et les matières minérales sont en corrélation très intime. Ce qui fait qu'un lait riche en gras l'est régulièrement aussi en tous les autres solides, que, par conséquent, la loi du paiement du lait selon sa teneur en gras est très rationnelle, puisque cette base se trouve à inclure non seulement cette matière grasse, mais, par le fait même, toutes les autres substances nutritives du lait.

On remarquera aussi que le lait de la vache canadienne est celui qui est le moins sucré, c'est-à-dire celui qui a la plus faible teneur en lactose; mais par ailleurs, sa proportion de matières minérales est plus élevée que dans tous les autres laits. C'est donc dire que c'est un lait riche, en même temps que reconstituant du système sanguin et osseux de l'organisme qui le consomme.

Après la Jersey et la Guernesey, on peut donc affirmer, sans crainte de se tromper et en se basant sur les chiffres plus haut cités, que c'est la vache canadienne qui donne le lait le plus riche, dépassant de près de 1% celui de la Holstein.

N.B.—Les chiffres cités au tableau pour les races autres que la Canadienne, sont empruntés au livre "Nutrition of Farm Animals", page 473, par Armsby.

LE PROBLEME DE L'EAU DANS LE SUD DE LA SASKATCHEWAN

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Introduction.—Les nombreux rôles biologiques et étiologiques de l'eau d'alimentation peuvent se résumer en quelques mots dans cette expression de M. le professeur G. Toupin: "L'eau est un puissant agent d'hygiène". En effet, chacun sait qu'elle est nécessaire à la vie et au fonctionnement de l'organisme, et que, pour satisfaire aux exigences de l'hygiène, une eau destinée à l'alimentation de l'homme doit être peu minéralisée et pratiquement dépourvue de matières organiques en dissolution. Si elle contient une proportion trop grande de sels minéraux, elle engendre des troubles physiologiques, notamment "intestinaux", qui aboutissent à la diarrhée.

Les eaux qui contiennent des matières organiques propagent facilement des germes septiques parmi les populations. Aussi, certaines maladies infectieuses sont souvent causées par des eaux de ce genre, telles, par exemple: la Dyssenterie, la Fièvre typhoide le Choléra et l'Entérite. A cette dernière sont redevables de nombreux cas de mortalité infantile.

Des faits.—Si nous établissions une enquête parmi la population de toute la partie sud de la Saskatchewan, nous constaterions avec surprise que la grande majorité des gens est vouée à la consommation d'une eau fortement minéralisée, ou d'une eau de glace. (*) L'eau chargée de sels minéraux, nous l'avons dit, est insalubre. Mais, celle qui provient de la glace, que vaut-elle? Elle vaut évidemment ce que valent les eaux des étangs, des "sloughs", des rivières d'où l'on retire la glace. Or, disons-le tout de suite, ces eaux sont généralement, sinon polluées, riches en matières organiques. Ainsi, le dosage de la matière organique de plusieurs échantillons d'eau de glace livrée à la consommation nous a fourni les résultats significatifs suivants:

Echantillons Nos 1 et 3:

Moyenne: 39 cc. solut. titrée de $KMnO_4$
Témoin: 20 cc. " " "
19 cc.; 0.0005 $\times$ 19 = 0.0095 gms.

Echant. Nos 2 et 4:

Moyenne: 28.25 cc. solut. titrée de $KMnO_4$
Témoin: 20.00 cc. " " "
8.25 cc.; 0.0005 $\times$ 8.25 = 0.0041 gms.

Si l'on examine la table des facteurs limites d'une eau en matières organiques, évalués en oxygène par la méthode au permanganate de potassium (table dont les valeurs ont été fixées par le comité d'hygiène de Paris), l'on constate que

une eau pure doit contenir moins de 0.001 gms.
" " potable " " " 0.002 "
" " suspecte " " " 0.004 "
" " mauvaise " plus de 0.004 "

de matière organique au *litre.*

Se fondant sur cette classification, l'eau des échantillons 2 et 4 qui contient 0.0041 gms. de matières organiques en oxygène au litre, est *mauvaise*, et celle des échantillons 1 et 3 devrait être qualifiée de *"très mauvaise"*.

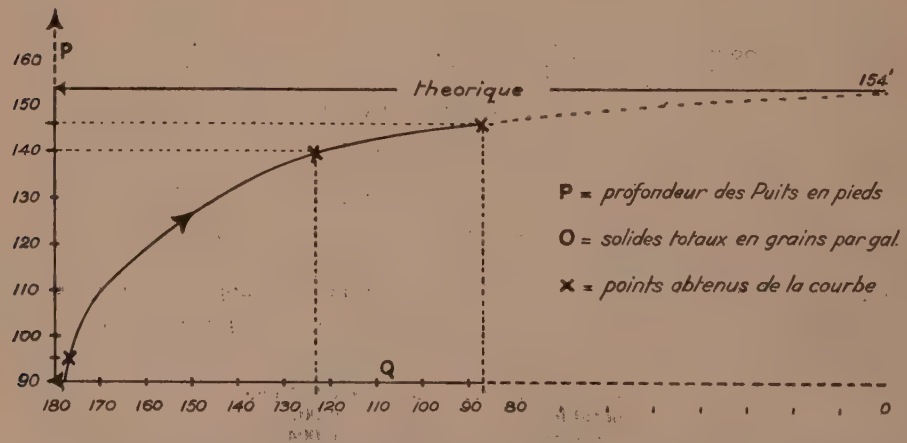
Donc, toutes deux sont scientifiquement condamnables sous le rapport de la matière organique, car celle-ci constitue le substratum de prédilection pour le développement des microbes. D'aucuns diront: "Tous ces microbes sont détruits par le froid". C'est une affirmation bien gratuite que celle-là. Nous savons par expérience que de nombreuses espèces bactériennes résistent par sporulation ou par d'autres modes d'involution à des froids plus intenses que ceux qu'elles ont à supporter dans l'Ouest.

* * *

En présence d'un tel état de choses, nous avons pris l'initiative de nous occuper de cette question d'importance vitale qu'est l'eau d'alimentation humaine. Cette question constitue, dans le sud de la Saskatchewan, un problème complexe, mais que nous croyons néanmoins susceptible d'être résolu. La pensée de pouvoir travailler efficacement peut-être à la solution de ce problème, c'est-à-dire, à l'amélioration de l'eau de consommation, nous est venue à l'esprit l'année dernière, alors qu'il nous fut permis de comparer les qualités différentielles de plusieurs échantillons d'eau provenant de diverses profondeurs. En effet, les quelques analyses minérales que nous avons eu l'occasion de faire, et dont les résultats sont tabulés ci-dessous, démontrent clairement que la teneur d'une eau en solides totaux varie sensiblement en fonction inverse de la profondeur du puits, à condition toutefois que le liquide soit amené à la surface par un système de tuyauterie. Si l'on n'envisage que les deux variables *profondeur* et *solides totaux*, nous avons pour le moment, l'échelle suivante:

Puits étudiés

Nos	profondeurs (en pieds)	solides totaux (en grains par gallon)
I	90	177.8
III	95	177.1
IV	140	123.0
II	146	86.7



Cette variation semblerait s'expliquer par la constitution géologique du sous-sol. Mais nos recherches, jusqu'ici partielles et localisées, ne nous

permettent encore aucune affirmation. Cependant, l'étude assez détaillée des matériaux d'un puits, ainsi que des investigations empiriques effectuées sur plusieurs autres puits placés dans des conditions quelque peu différentes, nous incitent à continuer nos recherches dans la direction présumée. Les matériaux que nous avons étudiés avec le plus de soin proviennent d'un puits creusé sur la propriété du collège Mathieu de Gravelbourg. Ce puits a une profondeur totale de 146 pieds et fournit une eau jaillissante à la surface. Son débit est de 720 gallons par jour à 5 pieds, et de 960 gallons à 2 pds de la surface du sol. Le forage a été pratiqué en mai 1929, et les matériaux étudiés au fur et à mesure. Nous avons ainsi un profil du sol à l'endroit même du puits donnant successivement de haut en bas, les couches géologiques suivantes:

(a) Argile, (b) Stéatite ou Soapstone, (c) Sable fin.

La couche d'argile d'une épaisseur moyenne de 100 pieds est constituée dans sa zone supérieure de Kaolin associé à des impuretés, telles que du carbonate de calcium, des oxydes de fer et des matières organiques. Dans la zone inférieure les sédiments argileux contiennent en plus de la silice granuleuse, tandis que la matière organique fait presque complètement défaut. Cette couche de sédiments argileux vraisemblablement de formation Laramie repose à sa base sur un stratum de Stéatite. Ce dernier se compose ainsi que nous l'enseignait M. le professeur H. M. Nagant, de silicates hydratés qui dérivent par altération de silicates préexistants tels que des variétés non ferrifères d'Amphiboles, de Pyroxènes et surtout de Péridots. A ces constituants naturels sont associés en quantités variables suivant la profondeur, des carbonates de calcium et de magnésium d'origine dolomitique, des sulfates de calcium et de magnésium et du carbonate de sodium. La couche de sable qui se trouve immédiatement au-dessous a été forée sur une épaisseur de 16 pieds. Elle est constituée de silice pratiquement pure et forme un sable à éléments fins.

Les trois couches brièvement décrites ci-dessus sont traversées par un tuyau de fer de 4½ pouces de diamètre, portant à sa partie inférieure un treillis en cuivre de 8 pieds de long. Ce treillis a 18 mailles au pouce linéaire et retient tout l'aggrégat susceptible d'être entrainé par le courant ascendant de l'eau.

Il existe dans la contrée plusieurs puits de ce genre et dans chaque cas il a fallu, pour s'assurer un débit convenable, forer au moins jusqu'au niveau de la couche de sable. Si à partir de ce niveau l'on continue le creusement, la quantité des sels minéraux de l'eau diminue. En présence de ces faits, nous sommes portés à croire que ce sont les infiltrations de la Stéatite qui souillent l'eau et la rendent impotable. En conséquence, il devrait y avoir à une certaine profondeur dans le sable une eau pratiquement pure.

Pour s'en assurer, il faudrait pratiquer un grand nombre de sondages en différents points de notre territoire,—analyser les échantillons d'eau et de terre prélevés à diverses profondeurs—comparer minutieusement les résultats obtenus. De plus, un tel travail nous permettrait de fournir des indications pour localiser l'eau potable en différents endroits.

Il est facile de se rendre compte qu'une telle entreprise servirait les intérêts de la population de nombreuses municipalités et d'une légion de colons habitant le sud de la Saskatchewan.

(à suivre)

*BULLETIN D'ANALYSE

Puits No. I; Profondeur 90 pieds; II—1930.

D° hydrotimétrique total $\frac{12}{2.4} \times 22 = 110.0$

D° " aprés ébullition b $= \frac{6.5}{2.4} \times 22 = 59.6$

D° " " addit. $(NH^4)^2C^2O^4$ c $= \frac{8}{2.4} \times 22 = 73.3$

D° " " ébullition + $(NH^4)^2C^2O^4$ d $= \frac{6}{2.4} \times 22 = 55.0$

$CaSO^4 = ((b-3)-d) \times 0.0140 = 0.0224$ grms.

$CaCO^3 = ([a-(b-3)]-(c-d)) \times 0.0103 = 0.3615$

Sels de Mg. $= d \times 0.0345 = 1.8975$

$MgO = \frac{42}{345} \times 1.8975 = 0.2310$

$MgCl^2 = \frac{90}{345} \times$ ——— $= 0.4950$

$MgCO^3 = \frac{88}{345} \times$ ——— $= 0.4840$

$MgSO^4 = \frac{125}{345} \times$ ——— $= 0.6875$

Fe^2O^3 (précipité par NH^4OH à l'etat $Fe(OH)^3$, pesé = 0.5400

Na^2CO^3 (caract. et précipit par le periodate basique de K, à l'état $I^2O^6Na^2H^3$ = 0.0586

Matière organique en oxgène par K Mn O^4; 5×0.0005 = 0.0025

$CO^2 = (c-d) \times 0.0099$ = 0.1812

Cl^2; (précipité par 120cc. $S\frac{N}{10}$ (Ag NO^3) et calculé = 0.0594

Pureté totale 110° hydrotimétriques
" permanente 59.6° "
" temporaire 50.4° "

SOLIDES TOTAUX 2.88 grms. par litre ou 177.8 grains par gallon.

F. G. CORMINBOEUF,
Analyste.

William John Rutherford

It came as a great shock to many members of the C.S.T.A. when they learned that Dean Rutherford of the University of Saskatchewan had passed away. His many friends knew of his serious illness, had learned of the plucky fight he was waging against heavy odds and had breathed a sigh of relief when it was announced that he had rounded the turn toward recovery and was well on his way back to health. The news of his relapse had not gone forth when we read the announcement of his death. Worn by successive attacks of ill health, the shock of his last sickness proved too powerful and the human dynamo of work and service we had known as Dean Rutherford was lost from the ranks of technical agriculturists.

Dean Rutherford was born in 1868. He was a graduate of the Ontario Agricultural College, where, in addition to his colleagues among the undergraduates, he built up enduring relationships with a host of later students when he acted as resident master at that institution. Many are the tales that Guelph old boys love to tell of their unique relationship with him who fathered their life at the college.

Dean Rutherford has been for many years an outstanding figure in Saskatchewan, particularly in his headship of his faculty in the University at Saskatoon. Shrewd, kindly, always a fearless but constructive critic, his was a personality that never lacked in impressiveness. He was a devoted lover of good livestock, with all the best that predilection implies and perhaps the tribute he would at heart treasure most was the recognition of his very successful efforts to foster interest in good Clydesdale horses. His interests, however, were quite diversified. His interest in better marketing conditions was rewarded by a membership, one of three, in the famous Royal Grain Enquiry Commission, appointed by the Government of Saskatchewan to enquire into the handling of export grain. In addition to this he strove for all that was best in scholastic attainment and was ever an apostle of true culture for agriculturists. We who follow cherish the memory of this great servant of agriculture and humbly bow to the fine tradition he has left for our guidance.

E. A. H.

APPRECIATION OF THE LATE FRED GRINDLEY *

H. Barton

Mr. President:

For the first time in the history of this society, our convention opens with Fred Grindley absent. This is a sad experience for us. There are many I know who would like to add to the tributes that have already been spoken and written. Splendid as they are, I doubt if any one could adequately express what is in our hearts, but we cannot let this occasion pass without once more giving some expression to what we feel.

Mr. Grindley was more than a secretary to this society. In the minds of many, he was the C.S.T.A. Without a doubt he was the personification of it. But he was more than that to all of us,—he was the warm personal friend of every one.

I am proud to claim him as one of Macdonald's first graduates, and loyal as he was to his Alma Mater, his was no narrow loyalty. He was not the kind of fellow whose loyalty took the form of selfish interest. He was just as loyal to every other institution he served and the proof of that is seen in the fact that he was admired and loved by the graduates of all agricultural institutions in Canada and elsewhere.

I believe everyone recognizes in some degree the contribution Mr. Grindley made. I wonder if the full record of his service will ever be known. It was my privilege to be intimately associated with him in what he afterwards called the dark days of the society; when the membership represented a small minority of the eligible list; when the purpose of the society was little understood and often misconstrued; when there was neither copy nor advertisement for a single advance issue of the magazine and no provision for publishing it; when the deficit in the funds of the society made it impossible for Mr. Grindley to receive his salary; and when he suffered physical handicap and personal criticism in the efforts he made. There are few who face such odds. But Mr. Grindley had set himself a task. Nothing could shake his faith in it, nothing could turn his hand from it. He bore his burdens cheerfully for the rest of us and there could be no finer example of unselfish devotion, grim determination, dogged but cheerful perseverance, tactful, honest, skillful service. The C.S.T.A. could have no better inspiration for the work that lies before it.

I expect the Committee will present a resolution expressing our appreciation, gratitude and regret to Mrs. Grindley, who some of you may not know made many things possible for Mr. Grindley, to whom this society owes a great deal, and without whom I feel Mr. Grindley would not have lived to see his ambition realized.

*This tribute was paid to the late General Secretary of the Canadian Society of Technical Agriculturists and Managing Editor of *Scientific Agriculture* at the opening of the business sessions of the C.S.T.A. tenth annual Convention held at Wolfville, N.S., on June 24, 1930.

CANADIAN SOCIETY OF TECHNICAL AGRICULTURISTS

Tenth Annual Convention *

Perhaps too close to the convention of 1930 to enjoy a proper perspective, one is nevertheless faced with a strong urge to set down certain impressions while they are still fresh in one's mind. Reading the programme proper it would appear that this year's convention was just another of those interesting conferences which we have grown to expect in connection with the annual stock-taking of our Society. The concensus of opinion among this year's delegates, however, was that this convention was somewhat different. Since we must perforce accept this verdict, there can be no harm in commenting upon possible causes.

The impression, perhaps general in its nature, that stands out in strong relief, is that it was a happy thought that prompted the executive to stage the convention of this year in the Maritimes. While it is a goodly land that embraces these provinces and while the most callous among us must have been deply impressed by what generous nature has lavished upon Eastern Canada in hill and dale, in river, lake and in-reaching ocean, yet that is not all nor nearly all. Scenery is not necessarily a part of our business programme, neither may we ascribe the happy atmosphere of the convention wholly to the kindly hospitality and studied thought for our comfort on the part of the competent and efficient committee that ordered our well-being during the days we foregathered, because we have become pleasantly spoiled by Canadian hospitality in whatever province we meet. There were some special pictures, however, which we have hung upon the walls of memory and these are hereby shown to those who care to look.

We saw a land that is old, in terms of Canada, and with that age has come, so we think, a calmness, a poise, a dignity that must prove an inspiration to those of us who dwell in lands we have "overrun but not yet occupied." It was good for the souls of thoughtful men to experience at first hand and on every hand a contact with a culture that properly values the higher things in life at their true worth.

We saw experimental farms and a school of agriculture which heretofore were but names to many of us. Here we saw not only work in agricultural experiments and demonstration, but we found centres for encouraging an appreciation of beauty and taste, so much so that many of us almost forgot about the investigation work we were supposed to study.

We were most happy in our entertainment at the old institution of Acadia and it is quite patent to most of us that the purposes of our annual convention are best served by meeting at some educational seat, not only because of the kindly reminiscences involved but because we seem to get our work done better in such an environment. Not the least happy among the many experiences of the week was the special convocation at which Acadia honoured four of our outstanding members by conferring upon them the honorary degree of D. Sc.

*Contributed by a Western delegate at the request of the Acting General Secretary.

MILLSTONE FROM FIRST GRIST MILL IN NORTH AMERICA, NOW BEARING C.S.T.A. TABLET

Inscription on Tablet: "This stone, brought from France about 1610, ground some of the earliest grain grown by white men in the soil of North America. It is here set up to commemorate that fact on the occasion of the visit of the Canadian Society of Technical Horticulturists to Annapolis Royal, June 23rd, 1930".

The most unique event of all however, as well as the most impressive was the unveiling of a tablet presented by the C.S.T.A. to the park authorities of Fort Anne at old Annapolis Royal, a tablet that now rests upon the millstone that first ground grain in North America. This stone, brought over from France, was once set up a short distance from the site of the fort, at a spot selected for the utilization of water power, where the ruins of the dam are still to be seen. The site of the fort is conceded to be where the first grain was sown, reaped and threshed, and now within what is left of the fort construction, an historical museum is well under way. Here the old millstone, bearing our tablet, rests. It gave one a wonderful thrill even partially to sense the drama, as the group of scientists who are striving for the latest in agriculture, stood reverently within the historic ramparts, to do honour to those who first sowed the seed and gathered the harvest on this continent. What a worth while linking of our present with that far gone year of 1607 !

We might easily be led into long comment upon the many striking agricultural areas to be found in the Maritimes, the wonderful unfolding of prospect in the St. John Valley, the justly famed fruit valley of Annapolis, the great stretches of the Tantramar marshes and other dyke lands and, last but not least, that stretch of red soil making up a province that her sons so proudly speak of as "The Island." Such, however, was not our purpose in writing this word—it was just to record some of the reasons why this year's convention was different.

As to the convention proper, it was a success. The sessions were well attended, the discussions for which more time should be allowed, were voted thus far satisfactory. The scientific lectures were warmly appreciated. A great deal of useful work was accomplished. So then, all in all, from first to last the convention was a success, because it was thoughtfully planned and well staged.

E.A.H.

CONCERNING THE C.S.T.A.

The August issue of this journal will contain a complete report of the Tenth Annual Convention of the Canadian Society of Technical Agriculturists, held at Wolfville, N.S., June 23rd to 26th, 1930. The presidential address of Professor J. P. Sackville, the annual report of the Acting General Secretary of the Society, the reports of the Standing Committees adopted at the convention and much other information of general interest will be covered in this report.

The August issue will complete Volume X of *Scientific Agriculture* and will therefore include a subject and author index for the year.

A few of the more important items of business transacted during the annual convention, or at meetings of the Board of Directors, were as follows:

1. The following recommendations were made by a special committee on Publications:

(a) The most important consideration which came before the committee had to do with the present form of the journal in relation to the service which it renders to the membership. It was pointed out that the journal is not read, and therefore not appreciated, by a considerable portion of the members because of the technical nature of the articles and that there exists in many quarters an insistent demand for less technical articles on current agricultural topics of scientific interest. The justice of this view from the standpoint of the non-specialist was recognized. At the same time, the contention that investigators were greatly favoured by receiving the journal in its present form could not be maintained in view of the fact that the published articles cover so many fields that only a very few articles in any one field appear in each volume. It is a fact also that survey articles on scientific topics and articles on the objects, methods and results on extension phases of agriculture have always been welcomed by the journal.

It was felt by all members of the committee that the journal in its present form has given the Canadian Society of Technical Agriculturists a status as a scientific society which can be retained only by maintaining a high standard in the quality of the studies which it publishes. In this respect the journal has made great strides during the last few years and at present it is a bulwark of strength to the society. Because of this fact it is supported by valuable contributions which go a long way toward defraying the expense of publication.

While the committee recognizes the value of the journal in its present form, they are equally impressed with the necessity of serving all sections of the membership. This would seem to be part of a larger subject which may be investigated best perhaps by the Committee on Educational Policies since this committee, during the coming year, plans to study the extension phases of its problem. In any case it does not seem feasible to ask the newly appointed General Secretary and Managing Editor to institute any fundamental change in the publication policy during his first year of office. In the meantime it should be possible to ask for and secure a frank discussion by the membership in the local branches.

(b) The committee considered again the recommendation of last year that scientific and non-scientific articles by Canadian authors be abstracted and published in the journal. Circumstances made it impossible to undertake the work during the past year although plans had been made for doing so. The committee now recommends that it be deferred for another year. There is great technical difficulty in getting the abstracting done properly and considerable doubt as to its ultimate value. Besides this undertaking would add much to the work of the secretary during the coming year.

(c) It is recommended that book reviews in *Scientific Agriculture* be accepted for publication only from men who are competent to do the reviewing fairly and well, preferably members of the C.S.T.A. Reviews submitted by publishers may be misleading.

(d) The question of increasing the subscription price of the journal to non-members was submitted for our consideration. It was suggested that

the price be raised from $3.00 to $5.00. The committee did not feel at liberty to deal with this matter since it seemed to be largely a question of financing and expediency requiring the recommendation of the secretary.

(e) A motion was submitted by the British Columbia branch recommending to the Dominion Executive the advisability of issuing an annual supplement to C.S.T.A. "Who's Who," containing particulars of members who have joined the society since the publication of the last volume and to be sent to all those having a copy of the "Who's Who." It seemed to the committee that since an annual list of members is published in May of each year which is sent to every member, that a supplementary "Who's Who" should not be necessary. This could not be done without considerable expense and the supplementary list of new members would be more up-to-date than the original. A new "Who's Who" will doubtless be published at suitable intervals of a few years.

(f) It was suggested that a new C.S.T.A. handbook for members should be prepared similar to the one published in September 1927. The Committee recommends that under the circumstances the issuing of a new handbook might be deferred another year unless it was found advisable to do so by the general secretary. When a new one is published it should be prepared in both English and French.

2. Mrs. Fred. H. Grindley was elected to Honorary Membership in the Society.

3. Dr. A. T. Charron, Assistant Deputy Minister of Agriculture for Canada, was awarded a Fellowship by the Society.

4. E. S. Archibald, W. S. Blair, J. A. Clark and W. T. Macoun, received the Honorary Degree of D.Sc. from Acadia University, at a Special Convocation Ceremony held on June 25th, 1930.

5. The five T. Eaton Company Scholarships for 1930 were awarded to the following:

Robert Prescott Longley (McGill, 1930, B.S.A.). Research subject, "Agricultural Economics." $600.00 scholarship.

Harold Charles Moss (Saskatchewan, 1924, B.S.A.). Research subject, "Soil Fertility with reference to Canadian Soils," to be taken at the University of Alberta. $600.00 scholarship.

Donald Fulton Putnam (Toronto, 1927, B.S.A.). Research subject, "Plant Pathology," to be taken at Macdonald College (McGill University). $600.00 scholarship.

Ralph Clifford Russell (Saskatchewan, 1924, B.S.A., 1926, M.S.A.). Research subject, "All phases of the take-all problem in Saskatchewan," to be taken at the University of Toronto. $600.00 scholarship.

Robert David Sinclair (Alberta, 1918, B.S.A., Iowa, 1926, M.S.). Research subject, "Animal Genetics and Animal Nutrition," to be taken in Great Britain. $1,200.00 scholarship.

6. The Board of Directors at a meeting held on June 26th, appointed Mr. H. L. Trueman to the position of General Secretary of the Society and Managing Editor of *Scientific Agriculture*.

7. The Board of Directors accepted an invitation to hold the 1931 convention of the Society at the Ontario Agricultural College, Guelph, Ont.

8. The following resolutions were passed on the recommendation of the Committee on Resolutions:

RESOLVED that the full thanks of the Canadian Society of Technical Agriculturists be expressed to all who have bestowed on this convention kind courtesies,—Acadia University for use of campus and buildings and for special convocation; the Departments of Agriculture of the three Maritime Provinces and the four Dominion Experimental Stations for generous hospitality and entertainment; the Government of Nova Scotia for their banquet, the Prince Edward Island Motor League and the Charlottetown Board of Trade for their services during the trip to the Island, the Mayor of Annapolis Royal and the Honorary Superintendent and Custodian of Fort Anne, L. M. Fortier, for coöperation in connection with the erection of the tablet on the historic millstone on the rampart of Fort Anne, Annapolis Royal, commemorating the beginning of agriculture by white men on the North American Continent, and for the privilege of being guided through the Fort Anne Museum.

RESOLVED that the Canadian Society of Technical Agriculturists express their very special appreciation to the chairmen and members of the various special Maritime committees for their most thoughtful and generous treatment and that they be congratulated upon the outstanding success of the convention.

RESOLVED that the hearty thanks of the Canadian Society of Technical Agriculturists be extended to the Dominion Department of Agriculture for its valued coöperation in providing lectures by eminent authorities from the United States at this convention.

RESOLVED that the Canadian Society of Technical Agriculturists, in tenth annual convention assembled, express their sympathy to Mrs. F. H. Grindley upon the loss of her husband, our esteemed and beloved General Secretary, who had been the guiding hand in the affairs of our organization during and since its inception.

RESOLVED that this annual convention of the Canadian Society of Technical Agriculturists record deep sense of loss sustained by the Society, and by agriculture throughout Canada, at the passing of Dr. J. W. Robertson and Dean W. J. Rutherford, and that our sympathy be expressed to Mrs. Robertson and daughter and to Mrs. Rutherford and family.

RESOLVED that the thanks of the Canadian Society of Technical Agriculturists be tendered to the T. Eaton Company for continuing to promote the interests of Agriculture by granting scholarships in agricultural research, thus bringing their contributions for this purpose, to date, to the sum of $9,000.00.

RESOLVED that the thanks of the Canadian Society of Technical Agriculturists be tendered to the Chilean Nitrate of Soda Educational Bureau for their much appreciated grant of $600.00 towards the cost of clerical assistance at Society headquarters.

RESOLVED that the thanks of the Canadian Society of Technical Agriculturists be tendered to all institutions giving grants to assist in the publication of *Scientific Agriculture*, namely, the National Research Council, the Dominion Department of Agriculture, Macdonald College, the Ontario Agricultural College, the Manitoba Agricultural College, the Universities of Saskatchewan, Alberta and British Columbia, and the provincial departments of Agriculture in Nova Scotia, New Brunswick, Ontario, Saskatchewan and Alberta.

RESOLVED that the thanks of the Canadian Society of Technical Agriculturists be tendered Dr. Robert Newton, Professor of Field Crops and Biochemistry, University of Alberta, Edmonton, for having made an exhaustive survey and presented an excellent detailed report on graduate instruction in agriculture in Canada.

RESOLVED that the deep appreciation of all members of the Canadian Society of Technical Agriculturists be conveyed to our special lecturers at the 1930 convention, namely Dr. J. H. Gourlay, Ohio Agricultural Experiment Station; Dr. L. J. Stadler, University of Missouri; Dr. G. Bohstedt, University of Wisconsin; Dr. G. H. Warren, Cornell University, and Mr. D. Akenhead of the East Malling Research Station.

RESOLVED that the Canadian Society of Technical Agriculturists wish to thank warmly, Miss Helen Henry, the President, the Honorary Acting General Secretary, and the members of the central executive for their splendid accomplishments throughout the heavy past year.

9. The following Committees were appointed for the current year, the Chairman of each Committee being named first:

Executive Council—W. T. Macoun, H. S. Arkell, Georges Bouchard, L. H. Newman, J. F. Booth, W. A. Weir, J. B. Fairbairn, P. N. April, J. G. Coulson.

Committee on Research—W. H. Brittain, A. M. Shaw, C. H. Goulden, W. R. Graham, W. Sadler, Robert Newton.

Committee on Agricultural Policies—E. A. Howes, F. H. Auld, J. B. Fairbairn, H. Barton, E. S. Archibald, G. H. Clark, C. F. Bailey.

Committee on Economics and Marketing—J. E. Lattimer, F. M. Clement, H. S. Fry, J. A. Carroll, J. F. Booth, H. C. Bois, H. S. Arkell.

Committee on Educational Policies—L. S. Klinck, C. E. Boulden, L. C. Roy, R. S. Duncan, N. C. Mackay, O. Aamodt, L. E. Kirk, E. E. Carncross, H. R. Hare, J. A. Clark, A. E. McLaurin.

Committee on Affiliations—J. M. Swaine, J. Coke, F. L. Drayton.

Committee on General Membership—H. G. Crawford, A. W. Baker, C. E. Boulden, Leo Brown, G. H. Dickson, W. M. Fleming, F. E. Foulds, J. M. Manson, R. R. McKibbin, P. M. Simmonds, W. W. Thomson, B. F. Tinney, P. H. Vezina, Stanley Wood, A. Godbout.

Employment Bureau Committee—E. S. Archibald, J. F. Booth, H. G. Crawford, A. T. Charron, H. L. Trueman.

Finance—J. B. Harrington, L. P. Roy, H. G. Crawford.

Progress—W. V. Longley, J. MacGregor Smith, A. E. Richards.

Membership—W. R. Graham, H. G. Crawford, F. N. Savoie.

Ballot—J. W. Mackay, J. W. Delaney.

Auditors—H. G. Crawford, L. S. McLaine.

Representative on Council of A.A.A.S.—W. T. Macoun.

Notes and News

A. M. Shaw (Toronto '10) has received the appointment of Dean of the Faculty of Agriculture at the University of Saskatchewan, Saskatoon, Sask.

W. R. Foster (Alberta '28) is now with the Dominion Laboratory of Plant Pathology, Saanichton, B.C.

G. E. Foucher (Montreal '22) has been appointed Tobacco Inspector for the Province of Quebec, under the Dominion Experimental Farms Branch. His mailing address is P. O. Box 126, L'Assomption, P. Q.

H. J. Siemens (Manitoba '25) has changed his address to suite M. Parkview Apartments, Brandon, Man.

J. G. DeJong (Manitoba '23), formerly Dominion Fruit Inspector in Manitoba, has been transferred to the Dominion Fruit Branch, c/o Canadian National Freight Office, Saskatoon, Sask.

J. K. Richardson (McGill '21), Assistant Plant Pathologist under the Dominion Department of Agriculture, has been transferred from Fredericton, N.B., to the Dominion Laboratory of Plant Pathology, St. Catharines, Ont.

J. G. Ferguson (Toronto '28) has changed his address to Copper Cliff, Ont.

F. X. Gosselin (Laval '23) formerly assistant County Agriculturist at Macamic, P. Q., has been appointed Junior Supervisor of Illustration Stations in Northern Ontario and Quebec, under the Dominion Department of Agriculture.

W. H. Wright (Toronto '12), who has been Supervising Analyst in charge of the Dominion Seed Branch Laboratory at Toronto, Ont., since 1920, has received the appointment of Chief Analyst under the Dominion Seed Branch with headquarters at Ottawa, Ont.

J. N. Bird (Toronto '23), has received the degree of M.S.A. from McGill University.

Applications for Membership

The following applications for regular membership have been received since June 1, 1930.

Anderson, A. W. (Toronto, 1915, B.A.) Saskatoon, Sask.

Black, J. (Dublin, 1904, A.R.C.S.) Toronto, Ont.

Currie, L. A. (British Columbia, 1930, B.S.A.) Cloverdale, B.C.

Bligh, R. D. L. (Toronto, 1915, B.S.A.) Kentville, N. S.

Drummond, W. M. (Toronto, 1923, B.A., Queens, 1924, M.A.) Toronto, Ont.

Kelley, D. R. (Toronto, 1924, B.S.A.) Stewiacke, N. S.

McEwen, W. H. (Manitoba, 1926, B.S.A.) Moncton, N. B.

Page, S. L. (Toronto, 1924, B.S.A.) Barrie, Ont.

Peden, E. E. (British Columbia, 1930, B.S.A.) Victoria, B. C.